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Component-I (B) - Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	Climatology
Module Name/Title	**Tropical Cyclones**
Module Id	**CL-23**
Pre-requisites	
Objectives	
Keywords	

Module 23

Tropical Cyclones

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Contents

Introduction

We all agree to the fact that USA is the super power of the world, but the super power fades when tropical cyclones strike it occasionally. This shows the power of tropical cyclones. Tropical cyclones represent a circulatory motion of air towards a low pressure centre. These cyclones are known by various names on the basis of characteristics, intensity and distribution.The origin and development of tropical cyclones requires presence of some favourable conditions. They are associated with violent winds and heavy rainfall and represent destructive weather phenomena with great loss of life and property. In this module, focus is on tropical cyclones – their genesis and development, distribution and associated weather conditions.

Learning Objectives

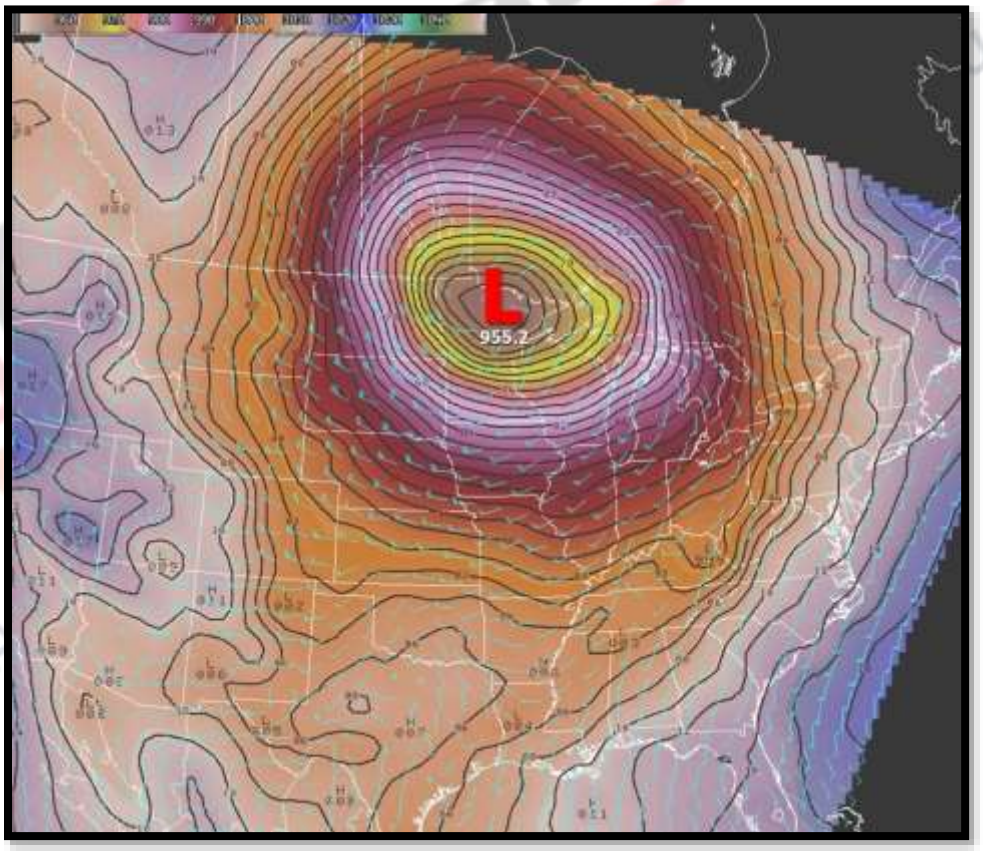
After studying this module, you will be able to:

- define and classify the tropical cyclones,
- explain the origin and development of tropical cyclones,
- highlight the general characteristics of tropical cyclones,
- explain weather conditions associated with the tropical cyclones, and
- describe the distribution of tropical cyclonesover the globe.

Tropical Cyclones

Tropical weather conditions prevail well beyond the Tropics of Cancer and Capricorn due to shifting of overhead position of sun. About half of the earth's surface and three-fourth of the world's population is concentratedin latitudinal zone between 30^0 N to 30^0 S. The low pressure centre-ward circulatory motion and associatedweather disturbances of this region are known as tropical cyclones. Generally, they have circular isobars, high velocity of winds and anticlockwise circulation in northern hemisphere (Figure 1). They generally originate on the western side of oceans within the tropics. Most of the tropical cyclones originate in the shifting doldrums region. Therefore, in Northern Hemisphere they are most frequent in August-October and in Southern Hemisphere during March-April.Tropical cyclones are not regular, predictive and uniform like temperate cyclones. There is a great variety of shape, size, wind velocity and weather conditions. These cyclones are known by various names on the basis of characteristics, intensity and distribution.

Figure 1:Typical Isobars in a Tropical CycloneDevelopment



Source: http://3.bp.blogspot.com/_jeetJTfzUoU/TMovh81Dh0I/AAAAAAAAJ4I/E7kLf6-8LFU/s1600/ExtratropicalCyclone-min-sfc-pressure-27Oct2010.jpg

Classification of Tropical Cyclones

The tropical cyclones are so diverse in size, characteristics and weather conditions that no two cyclones are similar and therefore, it is tough to categorise them in certain comprehensive classes. However, the tropical cyclones are normally classified into the following four types.

Tropical Disturbance

These are migratory wave-like cyclones which move east to west due to easterly trade winds. Thus, they are also popular as easterly waves. About 80 per cent of these disturbances occur between 5^0 and 20^0 N latitudes on the western side of the oceans. It has been noted that these disturbances originate near the boundary of trade winds with doldrums(ITCZ). They move westward at slow pace and are always accompanied by clouds mainly cumulus and cumulonimbus and moderate to heavy rainfall. A good weather before the disturbance is the general characteristic and it is followed by bad weather. Initially weather is fine and scattered cumulus clouds appear. It is followed by occasional rainfall, and finally by moderate to heavy rainfall from heavy cumulus and cumulonimbus clouds occurs. Occasionally, due to intense instability they may emerge as hurricanes.

Tropical Depressions

These are small size low pressure centres encircled by more than one closed isobars. The wind velocities are highly variable, but on an average remain about 40-60 km per hour. They occur most frequently in inter tropical convergence zone (ITCZ) and are rare in the zone of trade winds. They move in different directions. In summer season these disturbances influence the weather conditions of India and Australia. These depressions normally fail to attain the size of a storm and die out as weak disturbances.

Tropical Storms

These are low pressure centres encircled by closely placed isobars and have wind velocities in the range of 63 to 118 km per hour(Table 1). They are common in the Bay of Bengal, Arabian Sea, Caribbean Sea and in the vicinity of Philippines, especially during summer season. They are associated with heavy rainfall and storm surges in coastal areas. They frequently develop into more destructive type of tropical cyclones.

Table 1: Classification of Tropical Cyclones

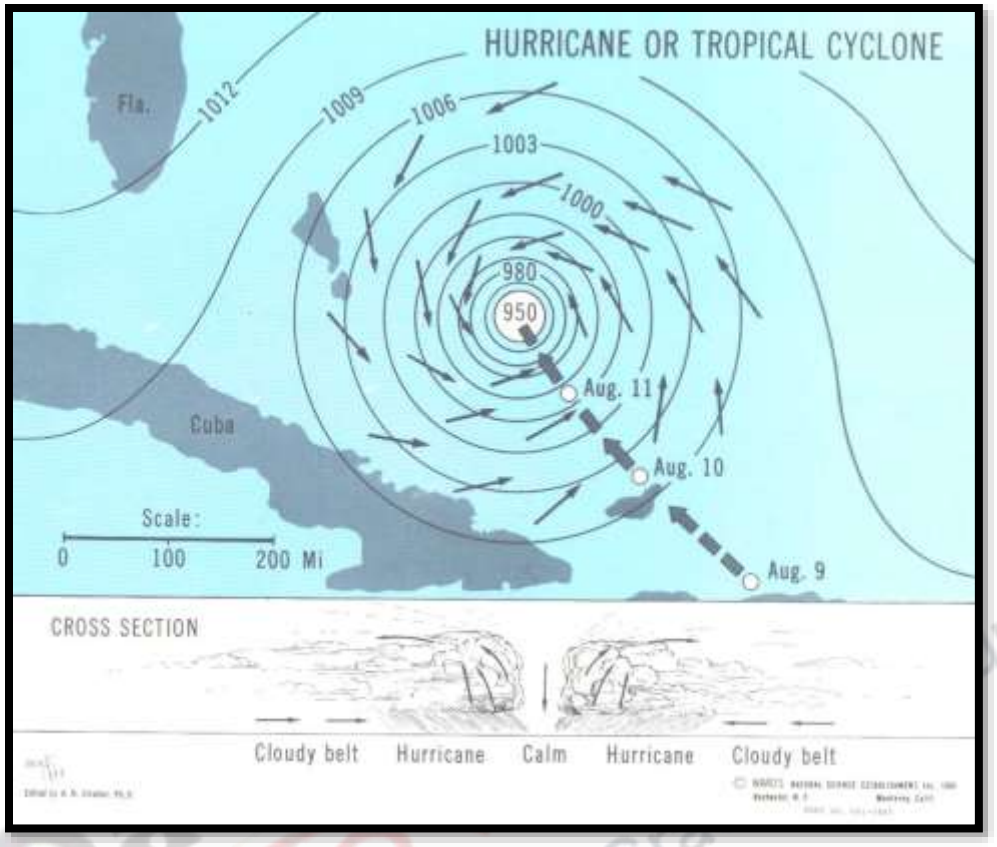
Name or Designation	**Winds Velocity**	**Characteristics**
Tropical Disturbance	Variableand low	Definite area of surface low pressure, originate near the boundary between trade winds and doldrums, life span one to two weeks and travel about 6^0 to 7^0 longitude per day, cumulonimbus clouds, as easterly waves move east to west.
Tropical Depression	Up to 63 kmph	Originate in ITCZ, more than one closed isobars, gale force, organising circulation, light to moderate rain.

Tropical Storm	63-118 kmph	Closed isobars, definite circular organisation, heavy rain and storm surge, assigned a name.
Hurricane/ Cyclone/Typhoon/Willy willies/Taifu	>119 kmph	Circular closed isobars, steep pressure gradient, heavy rain, storm surges, tornadoes in right front quadrant, well established eye, eye wall and spiral bands of vertical clouds

Hurricanes or Typhoons

Tropical cyclones are warm vortex circulatory wind systems of tropical origin with closed circular isobars. They have sustained maximum winds of at least 119 kmph and torrential rains. They are known by different names in different parts of the world.Hurricane represents most powerful and destructive tropical cyclone. This term is used for tropical cyclones of the Caribbean Sea and Gulf of Mexico region. The pressure gradient is very steep and at centre isobaric value may be 950 mb and pressure variation between centre and fringe may be 50 to 60 mb (Figure 2). Therefore, wind velocities are very high, with a minimum of 119 km per hour. The tropical cyclones of hurricane level force are called *typhoons* in the western North Pacific Ocean. They are known as *willy willies* in Australia, *cyclones* in Indian ocean, *baguio* in Philippines and *taifu* in Japan.Indian Meteorological Department (IMD) uses the term 'Severe Cyclone Storm' when the wind velocity exceeds 63 kmph and when above 119 kmph, it is called 'Severe Cyclone Storm with a core of Hurricane Winds'. Occasionally, when tropical cyclones have wind velocity above 200 kmph the term 'Super Cyclone' is used, for instance, the Super Cyclone of Odisha, October 29, 1999.

Figure 2: Hurricane



Source: http://faculty.uml.edu/nelson_eby/87.202/IMAGES/Tropical%20cyclone.jpg

Origin of Tropical Cyclones

The exact mechanism of origin and development of a tropical cyclone is still not well understood, but scholars have identified some conditions which are essentially associated with their formation. The formation of tropical cyclones depends upon fulfilment of the following requirements.

(i) **Continuous Supply of Large Amount of Warm and Moist Air**: It is a well observed fact that tropical cyclones originate only over large tropical ocean surface where temperature is 27^0C or above. The cold ocean currents lower the surface temperatures below this desired level on the eastern sides of the tropical oceans. Therefore, tropical cyclones originate in the western side of tropical oceans. As this condition is not fulfilled in the South Atlantic Ocean they fail to grow. It is noteworthy that this high temperature condition should prevail not just on surface but upto a depth of 60-70 metres deep from sea surface. Otherwise, convection process beneath cyclone will drag cooler water to surface and heat supply which is essential for cyclone will break. The power of a tropical cyclone depends on latent heat of condensation and thus, indirectly on supply of warm and moist air.Therefore, tropical

cyclones are most frequent over warmer tropical oceans and especially during warmer parts of the year.

(ii) **Strong Coriolis Force**: Although the temperature conditions are favourable at equator but tropical cyclones are absent. This is due to absence of coriolis force at equator which is a prerequisite for circulatory motion of air towards a low pressure centre, anticlockwise in northern hemisphere and clockwise in southern hemisphere. It is only at 5^0 latitudes that the minimum required level of coriolis force for deflection of winds prevails. Therefore, tropical cyclones are mostly concentrated in the belt of 5^0 to 30^0 latitudes. Though the coriolis force increases from equator (zero) to pole but the number of tropical cyclones does not follow this trend because the surface temperature of the oceans starts decreasing. Therefore, the tropical cyclones originate and develop most frequently between 10^0 and 20^0latitudes. Greater coriolis force is still more in the areas of increasing latitudes but the decline in the sea surface temperature does not allow the tropical cyclone to develop. It is also clear that factors do not operate in isolation rather together they determine origin and development of tropical cyclones.

(iii) **Upper LevelAir Divergence**: The upper troposphere (8 to 15 km) just above the surface disturbance must have well developed divergence or anticyclonic circulation to pump out the ascending air currents and to maintain continuous supply from below. This sustains convergence at surface and lifting mechanism in the cyclone which are its lifeline.

(iv) **Minimal Vertical Wind Shear**: Wind shear represents the differences between wind speeds at different altitudes. The ideal condition for tropical cyclone formation is of minimal vertical wind shear between lower and upper troposphere. In case, different wind directions and speeds operate vertically over an area, the latent heat carried aloft would be swept away and a circulatory core ascending area i.e. cyclone will fail to develop. For instance, in summer season over large parts of South Asia including India, cyclone formation is least active in July and August when surface monsoon winds and upper air easterly jet streams prevail simultaneously. Likewise the subtropical jet streams limit the extent of tropical cyclones towards temperate areas.

(v) **Existence of Mild Tropical Disturbances**: As mentioned in the types of tropical cyclones that the weak tropical disturbances such as easterly waves may occasionally develop into a large tropical cyclone. This happens when abundant warm and moist air results into the formation of intense column of latent heat induced instability. In addition to mild tropical disturbances, tropical cyclones develop around small atmospheric vortices in the ITCZ.

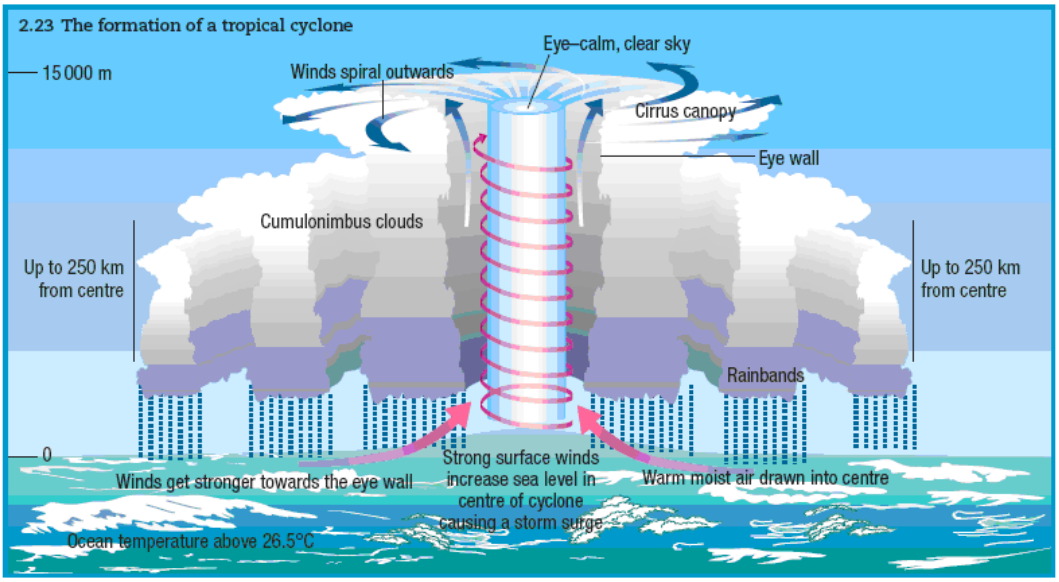
Structure of Tropical Cyclone

From the discussion so far, it is clear that tropical cyclones are circulatory motion towards low pressure centres. Winds circulation in a cyclone is anticlockwise in northern hemisphere and

clockwise in southern hemisphere. Structure of a typical tropical cyclone of hurricane level shows six distinct regions. These six regions from core to periphery are – (i) the eye of the cyclone, (ii) the eye wall, (iii) the spiral bands, (iv) the annular zone, (v) the outer convective band, and finally (vi) the trade winds cumulus.

The most important structural characteristic of tropical cyclone is the central part known as the eye of the cyclone. It is small central area of calm winds, clear skies and elliptical to circular shape. The eye wall is basically wall of vertical clouds i.e. cumulonimbus clouds. The eye wall region has the strongest winds and heaviest precipitation (Figure 3). The spiral shaped bands in satellite images give galaxy type appearance to cyclones (Figure 4). These rotating bands are associated with heavy precipitation, thunder and lightning. In the outer region of cyclone, subsidence tendency results into the formation of the annular zone. Here cloudiness is less extensive and high temperature and low humidity conditions prevail. This zone is surrounded by the outer convective band. Trade wind cumulus clouds constitute the outermost fringe of cyclone around which normal atmospheric conditions prevail.

Figure 3: Structure of Tropical Cyclone



Source:http://c9geonaturalhazards.wikispaces.com/file/view/Picture111.png/153462795/Picture111.png

Figure 4: Spiral Bands of Clouds and Eye of Cyclone

Source:http://mediad.publicbroadcasting.net/p/wusf/files/201305/hurricane.gif

Chief Characteristics of Tropical Cyclones

The chief characteristics of tropical cyclones are:

(i) Tropical cyclones mostly develop in tropical oceans between 5^0 and 20^0 latitudes, except the South Atlantic and the eastern South Pacific Ocean.

(ii) A great variety of tropical cyclones can be identifiedon the basis of shape, size and associated weather conditions. For instance, the average diameter of tropical cyclone is in the range of 80 to 300 km, but some have diameter of only 50 or even less km and others such as hurricanes in the range of 500-600 km;

(iii) The isobars are normally circular and closely placed, which means pressure gradient is steep and consequently the wind velocities are high. In case of hurricanes wind velocities of 120 to 240 km per hour are common and destructive;

(iv) The pressure gradient in hurricanes may be upto 50-60 mb (between eye and periphery). As per international standards, a hurricane must have at least 119 kmph sustained wind speed (averaged over a one-minute interval) and rotary wind circulation.

(v) They move in fairly well frequented tracks, initially they move westward under the influence of prevailing trade winds upto 15^0 latitude, after that they turn poleward (15^0 to 25^0) and finally turn towards east;

(vi) They are very strong over the oceans and travel over great distances but they become weak as they start moving overland and cold water. This is due to break in the continuous supply of warm and moist air;

(vii) Almost circular centre is the most characteristic feature of tropical cyclone which is called its eye. On an average, it has a diameter around 8 to 50 km. This well-known feature is associated with clear sky, calm and descending air, witnesses no precipitation.

(viii) Inward flow of warm and moist air approaches the central part towards the ground and it turns upward and ascends in a circulatory ring of vertical cumulonimbus clouds. This doughnut shaped wall of intense convective process surrounding the core is known as the eye wall. It is associated with strongest winds and heaviest rainfall.

(ix) At the top of the cyclone the air flow is outward, carrying the ascending air away from centre, thereby providing room for more inward (near surface) and upward flow.

(x) The eye wall of the cyclone is surrounded by the curved bands of clouds that are spread in a spiral manner.

(xi) The strong winds of cyclones blow anticlockwise in northern hemisphere, they spiral inward and increase in velocity towards centre, as the eye arrives over an area winds decrease or cease temporarily for sometime but again intensify to the previous levels. The wind direction becomes reverse to the previous phase of the cyclone.

(xii) These cyclones are energised by the release of latent heat of condensation and fusion (sublimation) associated with cumulus and cumulonimbus clouds. The release of latent heat warms the upper air and provides buoyancy for its ascending motion and it reduces the pressure near the surface. This promotes a more rapid inflow of airfrom the base. To get this heat engine started, large amount of warm and moist air is required which is provided by tropical oceans with surface temperature 27^0C or above,

(xiii) Tropical cyclones are natural disasters and result in loss of life and propertydue to storm surge, destructive winds and heavy rainfall, and finally

(xiv) Tropical cyclones decay or diminish in intensity due to their movement: – (a) over cool or cold ocean waters, (b) move over landmassesand gets weakened by surface friction, or (c) interact with cool air or cold air mass which makes large scale flow aloft difficult due to higher density. Therefore, the main cause for the dissipation of tropical cyclones is discontinuation of supply of large warm and moist air.

Distribution of Tropical Cyclones

Tropical cyclones are confined to tropical areas. The origin and developmentfrequency of tropical cyclones in the latitudinal range of 3^0-10^0 is about 22 per cent, in 10^0-20^0 about 65 per

cent and beyond this, it isabout 13 per cent(Figure 5). At equator and near equator they are absent due to absence of coriolis force and occurrence frequency is at peak in the central parts of tropics, and it again decreases due to absence of warm water surface with 27^0C temperature. The six major source regions of tropical cyclones are:

(i) **North Atlantic** (western tropical part): Mainly over Caribbean sea and Gulf of Mexico and maximum frequency is during August to October;

(ii) **Indian Ocean**: Bay of Bengal and Arabian Sea, with two maxima one in May and another in October-November;

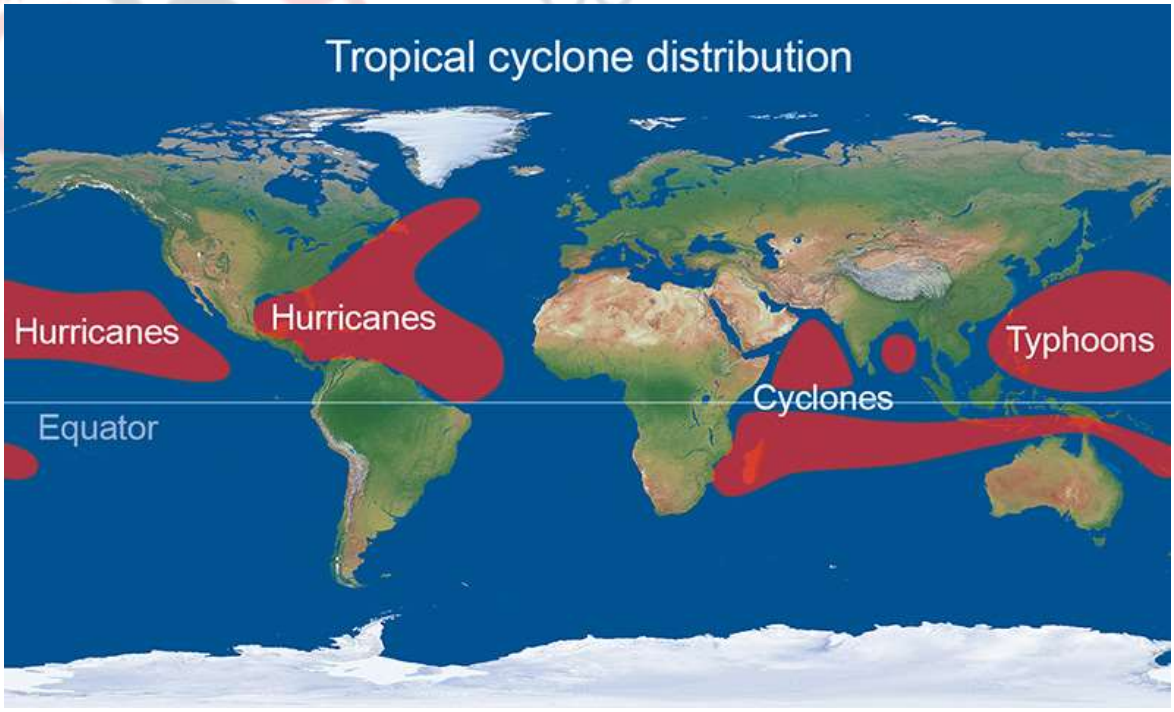
(iii) **South Indian Ocean:**The area extending from Madagascar and Reunion islands upto 90^0 E longitude and Timor sea in north-western Australia and mainly during January to March;

(iv) **North Pacific Ocean** (eastern tropical part): Over western coastal areas of Mexico and Central America upto California coast and maximum occurrence is during August to October;

(v) **North Pacific Ocean** (western tropical part):This region has maximum occurrence of cyclones in the world with maximum frequency in August and September and includes mainly, Philippines, China sea and areas around Japan;

(vi) **South Pacific Ocean** (western tropical part): east coast of Australia, in and around Samoa and Fiji Islands and around the Coral Sea region and majority occur during January to March.

Figure 5: Distribution of Tropical Cyclones



Source: https://www.metoffice.gov.uk/binaries/content/gallery/mohippo/images/migrated-image/a/tropical_cyclone_map.jpg

Destruction by Tropical Cyclones

Tropical cyclones are one of the most destructive disasters, and they are put under meteorological disastercategory. They result in great loss of life and property mainly in coastal areas. The damage caused by tropical cyclones is mainly associated with three actions – storm surge, destructive winds and inland freshwater (rain water) flooding (Figure 6A and 6B). The tropical cyclones are characterised by storm surge, destructive high velocity winds and exceptionally high rainfall causing flooding. Wind speedof upto 200 kmph and above, rainfall of 30 to 50 cm per day for several consecutive days and storm surge of 5 to 10 m high are not uncommon.

Figure 6A: Tropical Cyclone – A Meteorological Disaster

Source:https://d1o50x50snmhul.cloudfront.net/wp-content/uploads/2017/09/20193334/gettyimages-850005682.jpg

Figure 6B: Tropical Cyclone: Storm Surge and Flooding

Source:http://img.habervitrini.com/_GaleriFoto/6acb1c4a-7592-4ade-8c79-00b406dc98fa.jpg

Storm surges are abnormal rise of seawater in coastal areas due to tropical cyclone. It represents the height of water above the normal tide level and it is greatly amplified by local factors such as – shallow coastal water, estuarine or funnel shape of coastal region, fall in pressure over sea surface, tides, winds, the angle and speed with which the cyclone approaches the coast.Great storm surges are hazardous to shipping, drowning of human beings and animals along with destruction of vegetation and quantitative and qualitative loss of soil cover.High velocity winds in tropical cyclones damage installations, dwellings, natural vegetation and crops and communication systems. The third significant damaging process is flooding associated with torrential rainfall during cyclones. On the basis of the analysis of past storms, the Saffir-Simpson scale has been constructed to rank the hurricanes or tropical cyclones according to intensities in five classes (Table 2).

Table 2: Saffir-Simpson Hurricane Scale

		Wind Speed			
Category	*Central Pressure (millibars)*	*Kilometers per Hour*	*Miles per Hour*	*Storm Surge (meters)*	*Damage*
1	>979	119–153	74–95	1.2–2.5	Minimal
2	965–979	154–177	96–110	1.6–2.4	Moderate
3	945–964	178–209	111–130	2.5–3.6	Extensive
4	920–944	210–250	131–155	3.7–5.4	Extreme
5	<920	>250	>155	>5.4	Catastrophic

Source:http://web.gccaz.edu/~lnewman/gph111/topic_units/thunder_hurr/07_T02.jpg

Management of Tropical Cyclones

The mitigation strategies of tropical cyclonic disasters focus on integrated use of structural and non-structural measures. The structural measures include – construction of cyclone shelters, cyclone resistant buildings, sea dykes and embankments, canals, drains and surface water tanks safe transport and communication network. Non-structural measures include cyclone warning and forecasting, disaster risk management and capacity building by involving all stakeholders. The advance warning is the most effective way to reduce disastrous effects of tropical cyclones.
There are many techniques to generate data to detect and track tropical cyclones. Doppler weather radar, aircraft reconnaissance and latest and the most advanced is meteorological satellites to generate information to develop forecasts and to issue warnings.

Summary and Conclusions

Tropical cyclones represent circulatory motion of winds towards a low pressure centre.These cyclones are known by various names on the basis of characteristics, intensity and distribution. At macro level on the basis of intensity, they can be classified into two categories – (i) Weak cyclones – tropical disturbances and tropical depression; (ii) Strong and furious cyclones – tropical storms, hurricanes or typhoons and tornadoes. The exact mechanism of origin and development of a tropical cyclone is still not well understood but scholars have identified some conditions which are essentially associated with their formation. These are – (i) There should be continuous supply of large amount of warm and moist air – which means large tropical ocean surface where temperature is 27^0C or above; (ii) Strong coriolis force is a prerequisite for circulatory motion of air towards a low pressure centre, (iii) Upper level outflow or divergence; (iv) Minimal vertical wind shear; and (v) the existence of mild tropical disturbances.

The most characteristic feature of a tropical cyclone is eye of the cyclone and circular isobars. These cyclones are energised by the latent heat of condensation.The tropical cyclones of hurricane level force are called *typhoons* in the western North Pacific Ocean. They are known as *willy willies* in Australia, *cyclones* in Indian ocean, *baguio* in Philippines and *taifu* in Japan.The occurrence frequency of tropical cyclones in the latitudinal range of 3^0-10^0 is about 22 per cent, in 10^0-20^0 about 65 per cent and beyond this, it is about 13 per cent. They are absent at and near equator. There are six major source areas of tropical cyclones which are mainly concentrated on the western side of tropical oceans. The tropical oceans of South Atlantic and eastern South Pacific are the exceptions, where they do not occur.

Tropical cyclones are meteorological disasters and damage caused by them can be divided into three process associated with them namely, storm surge, destructive winds and flooding due to torrential rainfall. Integrated use of structural and non-structural measures is required to minimise the loss of life and property caused by tropical cyclones.

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