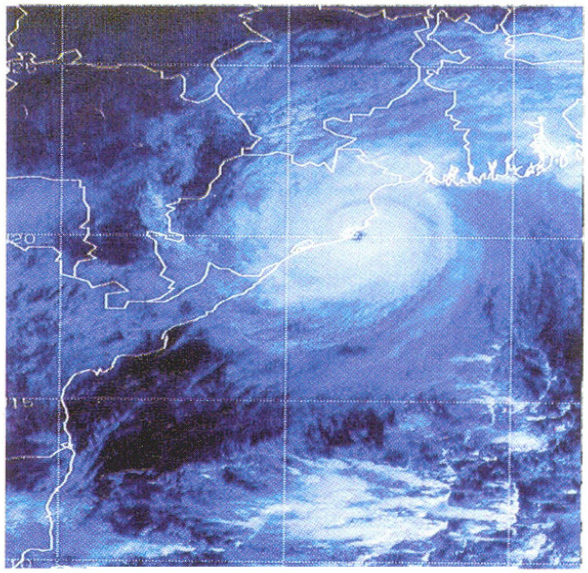
Frequently Asked Questions
on
Tropical Cyclones



Satellite picture (29 Oct., 0930 IST)
of 1999 Orissa Super Cyclone

- What is our accuracy of landfall prediction?
- How does IMD predict intensity of the cyclone ?
- What is the role of upper tropospheric westerly trough ?
- Why Tropical Cyclones weaken over land after landfall ?
- Doesn't the friction over land kill tropical cyclones?
- What are the abnormal characteristics associated with Tropical Cyclones?
- What is the organizational set up in IMD for Cyclone forecasting and Warning?
- What are the different bulletins issued by IMD in connection with the cyclone?
- What is 4-stage warning system for Tropical Cyclones?
- How frequently IMD issues these bulletins?
- Is there any order in mentioning the disastrous weather in the bulletin?
- What is port warning?
- What are fishermen warning?
- What is sea area bulletin?
- What is coastal weather bulletin?
- What is the meaning of widespread /fairly wide spread/scattered/isolated rainfall?
- What do you mean by heavy rainfall, very heavy rainfall and extremely heavy rainfall ?
- How does IMD mention state of sea in the bulletins?
- What is meaning of the reference time mentioned in the bulletin ?
- How are Cyclone Warnings disseminated ?
- What are the bulletins available in the website? What is the website address ?
- What is IVRS ? How does it work ?
- What is Cyclone Warning Dissemination System (CWDS)?
- Who are the recipients of Cyclone Warnings?
- How a common man gets information about a cyclonic storm?
- On the event of any doubt about approach of a cyclonic storm to whom a common man can approach to get authentic information (in absence of relevant AIR bulletins)?
- **How does IMD keep liaison with State officials?**
- What are the devastations which can not be protected by a common man and has to be mentally prepared to accept the loss?

What is a tropical cyclone?

A tropical cyclone is a rotational low pressure system in tropics when the central pressure falls by 5 to 6 hPa from the surrounding and maximum sustained wind speed reaches 34 knots (about 62 kmph). It is a vast violent whirl of 150 to 800 km, spiraling around a centre and progressing along the surface of the sea at a rate of 300 to 500 km a day.

The word cyclone has been derived from Greek word ‘cyclos’ which means ‘coiling of a snake’. The word cyclone was coined by Heary Piddington who worked as a Rapporteur in Kolkata during British rule. The terms "hurricane" and "typhoon" are region specific names for a strong "tropical cyclone". Tropical cyclones are called “Hurricanes” over the Atlantic Ocean and “Typhoons” over the Pacific Ocean.

Why do 'tropical cyclones' winds rotate counter-clockwise (clockwise) in the Northern (Southern) Hemisphere?

As the earth's rotation sets up an apparent force (called the Coriolis force) that pulls the winds to the right in the Northern Hemisphere (and to the left in the Southern Hemisphere). So, when a low pressure starts to form over north of the equator, the surface winds will flow inward trying to fill in the low and will be deflected to the right and a counter-clockwise rotation will be initiated. The opposite (a deflection to the left and a clockwise rotation) will occur south of the equator.

This Coriolis force is too tiny to effect rotation in, for example, water that is going down the drains of sinks and toilets. The rotation in those will be determined by the geometry of the container and the original motion of the water. Thus, one can find both clockwise and counter-clockwise flowing drains no matter what hemisphere you are located. If you don't believe this, test it out for yourself.

What does "maximum sustained wind" mean ? How does it relate to gusts in tropical cyclones?

India Meteorological Department (IMD) uses a 3 minutes averaging for the sustained wind. The maximum sustained wind mentioned in the bulletins used by IMD is the highest 3 minutes surface wind occurring within the circulation of the system. These surface winds are observed (or, more often, estimated) at the standard meteorological height of 10 m (33 ft) in an unobstructed exposure (i.e., not blocked by buildings or trees).

The National Hurricane Centre uses a 1 minute averaging time for reporting the sustained wind. Some countries also use 10 minutes averaging time for this purpose. While one can utilize a simple ratio to convert from peak 10 minute wind to peak 1 minute wind or 3 minute wind, such systematic differences to make interbasin comparison of tropical cyclones around the world is problematic. However there is no significant difference between the maximum sustained wind reported in different basis with different averaging method.

What is the energy potential of a tropical cyclone?

Tropical Cyclone can be compared to a heat engine. The energy input is from warm water and humid air over tropical oceans. Release of heat is through condensation of water vapour to water droplets/rain. Only a small percentage (3%) of this released energy is converted into Kinetic energy to maintain cyclone circulation (windfield). A mature cyclone releases energy equivalent to that of 100 hydrogen bombs.

How are low pressure system classified in India? What are the differences between low, depression and cyclone?

The low pressure system over Indian region are classified based on the maximum sustained winds speed associated with the system and the pressure deficit/ number of closed isobars associated with the system. The pressure criteria is used, when the system is over land and wind criteria is used, when the system is over the sea. The system is called as low if there is one closed isobar in the interval of 2 hPa. It is called depression, if there are two closed isobars, a deep depression, if there are three closed isobars and cyclonic storm if there are four or more closed isobars. The detailed classification based on wind criteria are given in the Table below. Considering wind criteria, the system with wind speed of 17-27 knots is called as depression and the low pressure system with maximum sustained 3 minutes surface winds between 28-33 knots is called a deep depression. The system with maximum sustained 3 minutes surface winds of 34 knots or more is called as cyclonic storm

System	Pressure deficient hPa	Associated wind speed Knots (Kmph)
Low pressure area	1.0	<17(<32)
Depression	1.0- 3.0	17-27 (32–50)
Deep Depression	3.0 - 4.5	28-33 (51–59)
Cyclonic Storm	4.5- 8.5	34-47 (60-90)
Severe Cyclonic Storm (SCS)	8.5-15.5	48-63 (90-119)

Very Severe Cyclonic Storm	15.5-65.6	64-119 (119-220)
Super Cyclonic Storm	>65.6	>119(>220)

Are all cyclonic storms equally dangerous?

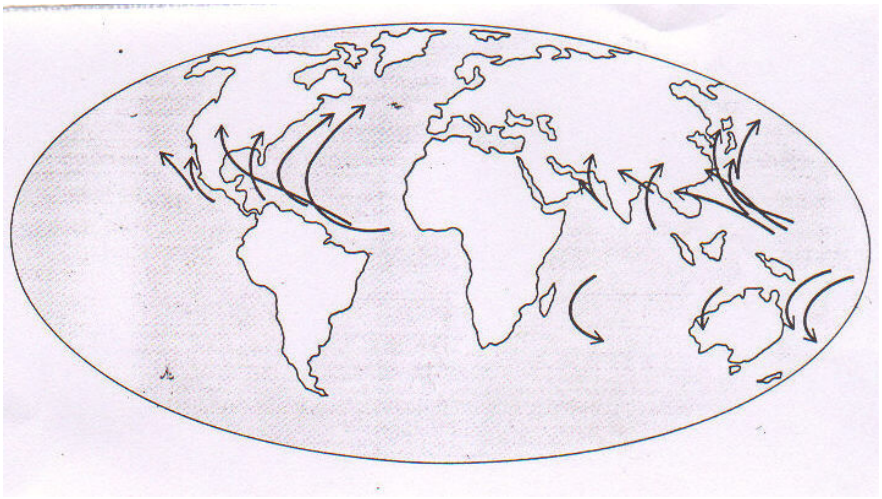
No, all cyclonic storms are not equally dangerous. More the pressure drop at the central region more will be the severity of the storm. The cyclonic storms are generally categorised according to the maximum wind associated with the storm. If the maximum wind is between 34 - 47 knots (about 60-90 kmph) it is called a Cyclonic storm. Severe Cyclonic storm will have maximum wind speed between 48 - 63 knots (about 90-120 kmph). If the maximum wind is 64-119 knots it will be called a very severe Cyclonic storm and when the wind is 120 knots and above it will be called super cyclonic storm. There is very little association between intensity (either measured by maximum sustained winds or by the lowest central pressure) and size (measured by radius of gale force winds)

What are the super cyclone, super-typhoon, a major hurricane and an intense hurricane?

When the maximum sustained 3 minutes surface winds are more than 119 knots, the low pressure system is called as "Super Cyclone" over north Indian Ocean. Similarly, “Super-typhoon" is a term utilized by the U.S. Joint Typhoon Warning Centre for typhoons that reach maximum sustained 1 minute surface winds of at least 130 knots (65 m/s). This is the equivalent of a strong Saffir-Simpson category 4 or category 5 hurricane in the Atlantic basin or a category 5 severe tropical cyclone in the Australian basin.

Where do tropical cyclones form?

The tropical cyclones form over ocean basins in lower latitudes of all oceans except south Atlantic and southeast Pacific. The tropical cyclones develop over the warm water of the Bay of Bengal and the Arabian Sea. The favourable ocean basins for development of cyclonic storms are shown in the figure below.



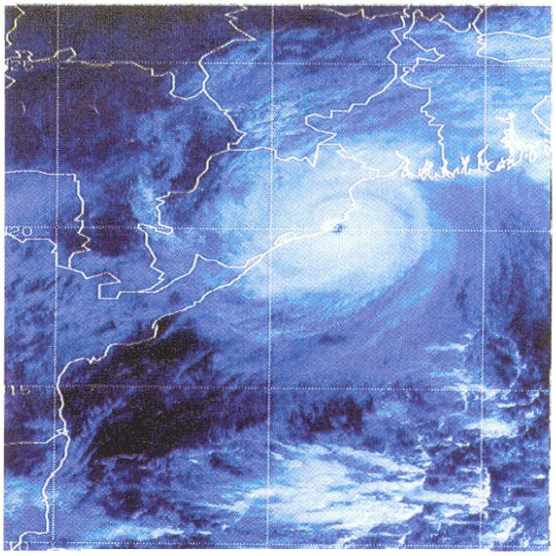
TC breeding grounds are located over certain ocean basins. Arrows indicate average trajectories over different basins

What is the size of a tropical cyclone over the north Indian Ocean

The size of a tropical cyclone over Indian seas varies from 50-100 km radius to 2000 km with an average of 300 –600 km.

What is the structure of a tropical cyclone?

A fully developed tropical cyclone has a central cloud free region of calm winds, known as the "**eye**" of the cyclone with diameter varying from 10 to 50 km. Surrounding the eye is the "**wall cloud region**" characterised by very strong winds and torrential rains, which has the width of about 10 to 150 km. The winds over this region rotate around the centre and resemble the "coils of a snake". Wind speed fall off gradually away from this core region, which terminate over areas of weaker winds with overcast skies and occasional squall .There may be one or more spiral branch in a cyclone where higher rainfall occurs. The vertical extent of the cyclone is about 15 km. The INSAT imagery of Orissa Super cyclone on 29th October, 1999 is shown in the figure below.



Satellite picture (29 Oct., 0930 IST) of 1999 Orissa Super Cyclone

What is a "CDO"?

"CDO" is an acronym that stands for **"central dense overcast"**. This is the cirrus cloud shield that results from the thunderstorms in the eyewall of a tropical cyclone and its rainbands. Before the tropical cyclone reaches very severe cyclonic storm (64 knots,), typically the CDO is uniformly showing the cold cloud tops of the cirrus with no eye apparent. Once the storm reaches the hurricane strength threshold, usually an eye can be seen in either the infrared or visible channels of the satellites. Tropical cyclones that have nearly circular CDO's are indicative of favourable, low vertical shear environments.

What is the "eye"? How is it formed and maintained? What is the "eyewall"? What are "spiral bands"?

The **"eye"** is a roughly circular area of comparatively light winds and fair weather found at the centre of a severe tropical cyclone. Although the winds are calm at the axis of rotation, strong winds may extend well into the eye. There is little or no precipitation and sometimes blue sky or stars can be seen. The eye is the region of lowest surface pressure and warmest temperatures aloft - the eye temperature may be 10°C warmer or more at an altitude of 12 km than the surrounding environment, but only 0-2°C warmer at the surface in the tropical cyclone. Eyes range in size from 8 km to over 200 km across, but most are approximately 30-60 km in diameter.

The eye is surrounded by the **"eyewall"**, the roughly circular ring of deep convection, which is the area of highest surface winds in the tropical cyclone. The eye is composed of air that is slowly sinking and the eyewall has a net upward flow as a result of many moderate - occasionally strong - updrafts and downdrafts. The eye's warm temperatures are due to compressional warming of the subsiding air. Most soundings taken within the eye show a low-level layer, which is relatively moist, with an inversion above - suggesting that the sinking in the eye typically does not reach the ocean surface, but instead only gets to around 1-3 km of the surface.

The exact mechanism by which the eye forms remains somewhat controversial. One idea suggests that the eye forms as a result of the downward directed pressure gradient associated with the weakening and radial spreading of the tangential wind field with height (Smith, 1980). Another hypothesis suggests that the eye is formed when latent heat release in the eyewall occurs, forcing subsidence in the storm's centre (Shapiro and Willoughby, 1982). It is possible that these hypotheses are not inconsistent with one another. In either case, as the air subsides, it is compressed and warms relative to air at the same level outside the eye and thereby becomes locally buoyant. This upward buoyancy approximately balances the downward directed pressure gradient so that the actual subsidence is produced by a small residual force.

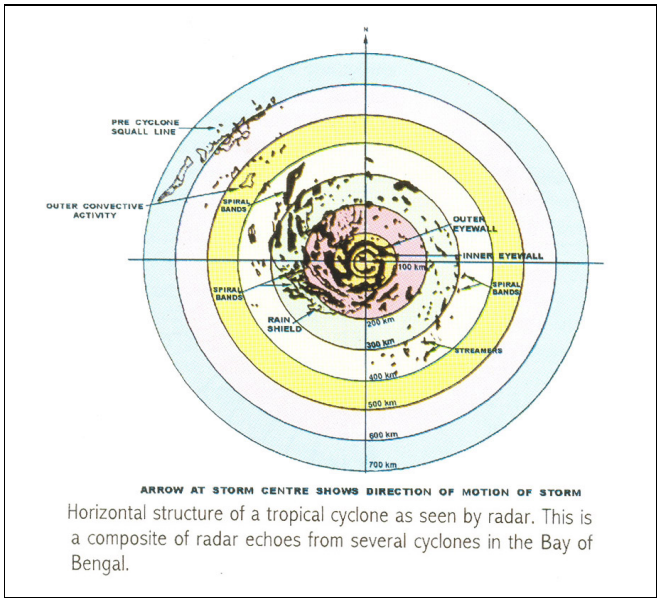
Another feature of tropical cyclones that probably plays a role in forming and maintaining the eye is the eyewall convection. Convection in tropical cyclones is organized into long, narrow rainbands which are oriented in the same direction as the horizontal wind. Because these bands seem to spiral into the centre of a tropical cyclone, they are called **"spiral bands"**. Along these bands, low-level convergence is a maximum, and therefore, upper-level divergence is most pronounced above. A direct circulation develops in which warm, moist air converges at the surface, ascends through these bands, diverges aloft, and descends on both sides of the bands. Subsidence is distributed over a wide area on the outside of the rainband but is concentrated in the small inside area. As the air subsides, adiabatic warming takes place, and the air dries. Because subsidence is concentrated on the inside of the band, the adiabatic warming is stronger inward from the band causing a sharp contrast in pressure falls across the band since warm air is lighter than cold air. Because of the pressure falls on the inside,

the tangential winds around the tropical cyclone increase due to increased pressure gradient. Eventually, the band moves toward the centre and encircles it and the eye and eyewall form.

Thus, the cloud-free eye may be due to a combination of dynamically forced centrifuging of mass out of the eye into the eyewall and to a forced descent caused by the moist convection of the eyewall. This topic is certainly one that can use more research to ascertain which mechanism is primary.

Some of the most intense tropical cyclones exhibit concentric eyewalls, two or more eyewall structures centreed at the circulation centre of the storm. Just as the inner eyewall forms, convection surrounding the eyewall can become organized into distinct rings. Eventually, the inner eye begins to feel the effects of the subsidence resulting from the outer eyewall, and the inner eyewall weakens, to be replaced by the outer eyewall. The pressure rises due to the destruction of the inner eyewall are usually more rapid than the pressure falls due to the intensification of the outer eyewall, and the cyclone itself weakens for a short period of time.

How does the cyclone look like in a Radar ?

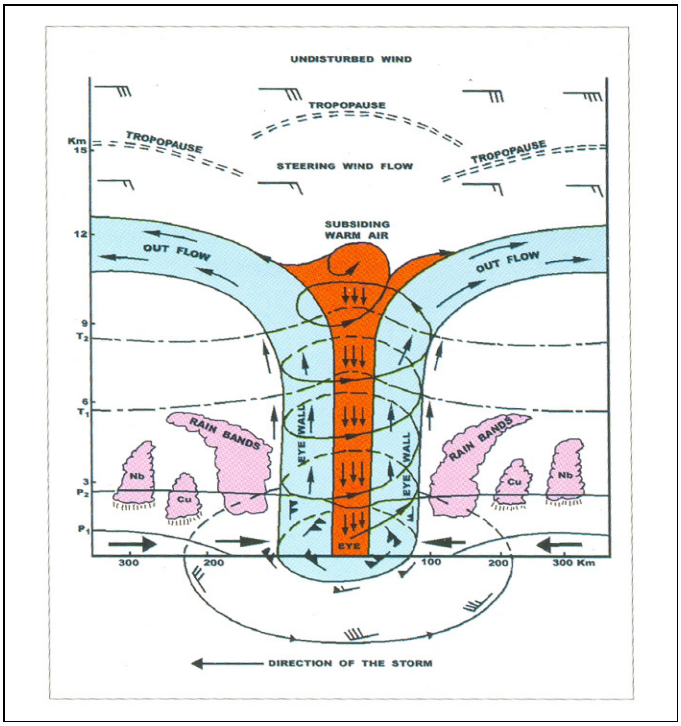


Horizontal structure of a tropical cyclone as seen by radar. This is a composite of radar echoes from several cyclones in the Bay of Bengal.

According to Radar imagery, a matured cyclone consists of eye, eye wall, spiral bands, pre-cyclone squall lines and streamers as shown in the above figure.

What is the wind structure in a cyclone?

The ideal wind and cloud distribution in a cyclone is shown in the following figure.



The band of maximum winds may vary between 10 and 150 Km. In this belt, speed decreases rapidly towards the eye of the cyclone. But it decreases slowly and in an irregular fashion outward from the eye wall.

How do the cyclones form and intensify?

In the tropics, weak pressure waves move from east to west. These are called easterly waves. Under favourable situation, a low pressure area forms over the area of an easterly trough. This gives rise to low level convergence. If the sea is warm (sea surface temperature > = 26.5^0 C) and there is sufficient upper level divergence i.e air is blown off at higher levels from the area of low pressure, the pressure gradually falls. Low level convergence coupled with upper level divergence gives rise to vertical motion taking moist air upwards. These moistures condense at higher levels (middle troposphere) and give out latent heat of condensation. Due to release of heat of condensation the area warms up resulting into further fall in pressure. This process continues and a low pressure

system gradually intensifies into a cyclonic storm.

Hence, for tropical cyclogenesis, there are several favourable environmental conditions that must be in place. They are:-

1. Warm ocean waters (of at least 26.5°C) throughout a sufficient depth (unknown how deep, but at least on the order of 50 m). Warm waters are necessary to fuel the heat engine of the tropical

cyclone.

2. An atmosphere which cools fast enough with height such that it is potentially unstable to moist convection. It is the thunderstorm activity which allows the heat stored in the ocean waters to be liberated for the tropical cyclone development.

3. Relatively moist layers near the mid-troposphere (5 km). Dry mid levels are not conducive for allowing the continuing development of widespread thunderstorm activity.

4. A minimum distance of at least 500 km from the equator. For tropical cyclogenesis to occur, there is a requirement for non-negligible amounts of the Coriolis Force (attributed to earth's rotation) to provide the near gradient wind balance to occur. Without the Coriolis Force, the low pressure of the disturbance cannot be maintained. This is the reason why the narrow corridor of width of about 300 km on either side of the equator is free from cyclones. Because of this there is no inter-hemispheric migration of tropical cyclones across the equator.

5. A pre-existing near-surface disturbance with sufficient vorticity (rotation) and convergence. Tropical cyclones cannot be generated spontaneously. To develop, they require a weakly organized system with sizable spin and low level inflow.

6. Low values (less than about 10 m/s or 20 kts) of vertical wind shear between the lower (1.5 km) and the upper troposphere (12 km). Vertical wind shear is the magnitude of wind change with height. Large values of vertical wind shear disrupt the incipient tropical cyclone and can prevent genesis, or, if a tropical cyclone has already formed, large vertical shear can weaken or destroy the tropical cyclone by interfering with the organization of deep convection around the cyclone centre.

The above conditions are necessary, but not sufficient as many disturbances that appear to have favourable conditions do not develop. However, these criteria fit well over the north Indian Ocean

What is the role of easterly waves on cyclogenesis in north Indian Ocean ?

It has been recognized since at least the 1930s that lower tropospheric westward traveling disturbances often serve as the "seedling" circulations for a large proportion of tropical cyclones. These disturbances are known as **easterly waves**. The waves move generally toward the west in the lower tropospheric trade wind flow. They are first seen usually in October to April. The waves have a period of about 3 or 4 days and a wavelength of 2000 to 2500 km. One should keep in mind that the "waves" can be more correctly thought of as the convectively active troughs along an extended wave train. Though, these waves are generated frequently, but it appears that the number that is formed has no relationship to how much tropical cyclone activity there is over the north Indian Ocean each year. It is currently completely unknown, how, easterly waves change from year to year in both intensity and location and how these might relate to the activity ?

Is there any extra-tropical cyclone?

Extra-tropical cyclones are low pressure systems with associated cold fronts, warm fronts, and occluded fronts. The **extra-tropical cyclone** is a storm system that primarily gets its energy from the horizontal temperature contrasts that exist in the atmosphere. Extra-tropical cyclones are low pressure systems with associated cold fronts, warm fronts, and occluded fronts. **Tropical cyclones**, in contrast, typically have little to no temperature differences across the storm at the surface and their winds are derived from the release of energy due to cloud/rain formation from the warm moist air of the tropics. Structurally, tropical cyclones have their strongest winds near the earth's surface, while extra-tropical cyclones have their strongest winds near the tropopause - about 12 km up. These differences are due to the tropical cyclone being "warm-core" in the troposphere (below the tropopause) and the extra-tropical cyclone being "warm-core" in the stratosphere (above the tropopause) and "cold-core" in the

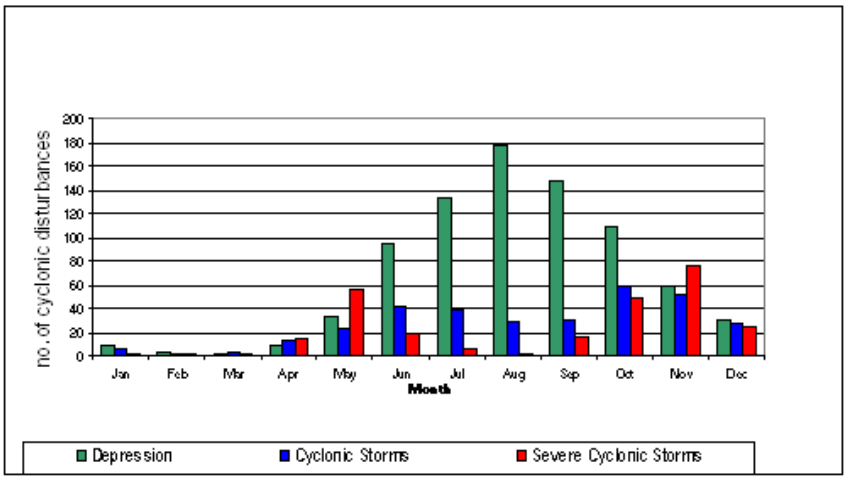
troposphere. "Warm-core" refers to being relatively warmer than the environment at any level.

Often, a tropical cyclone will transform into an extra-tropical cyclone as it recurves poleward and to the east. Occasionally, an extra-tropical cyclone will lose its frontal features, develop convection near the centre of the storm and transform into a full-fledged tropical cyclone. Such a process is most common in the north Atlantic and northwest Pacific basins. The transformation of tropical cyclone into an extra-tropical cyclone (and vice versa) is currently one of the most challenging forecast problems.

What is the annual frequency of Cyclones over the Indian Seas? What is its intra-annual variation?

The average annual frequency of tropical cyclones in the north Indian Ocean (Bay of Bengal and Arabian Sea) is about 5 (about 5-6 % of the Global annual average) and about 80 cyclones form around the globe in a year. The frequency is more in the Bay of Bengal than in the Arabian Sea, the ratio being 4:1. The monthly frequency of tropical cyclones in the north Indian Ocean display a bi-modal characteristic with a primary peak in November and secondary peak in May. The months of May-June and October-November are known to produce cyclones of severe intensity. Tropical cyclones developing during the monsoon months (July to September) are generally not so intense.

The frequencies of Cyclonic systems over north Indian Ocean during 1891-2006 are given in the figure below.



What are the average, most, and least tropical cyclones occurring in this basin?

The most, least and average numbers of cyclonic storms and severe cyclonic storms over the north

Indian ocean is given in the Table below:

- Minimum No. of cyclones in a year - One (1949)
- Maximum No. of cyclones in a year – Ten (1893,1926,1930,1976)
- Out of total disturbances - 35% intensify to Cyclones

16 % intensify to severe cyclones

07% intensify to very severe cyclones

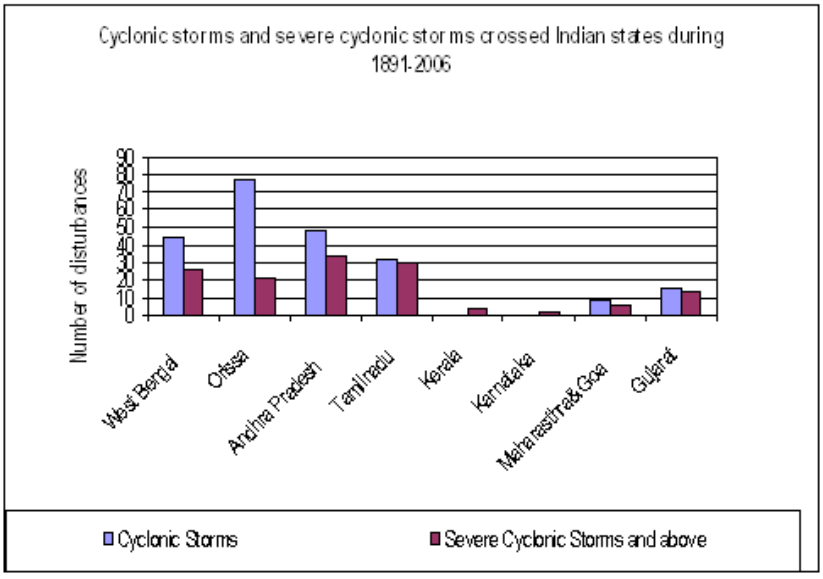
Basin	Cyclonic storm			Severe cyclonic storm		
	Most	Least	Average	Most	Least	Average
N Indian Ocean	10	1	5.4	6	0	2.5

How many severe tropical storms occur around the world and over north Indian Ocean every year?

About 20-30 severe tropical storms occur around the world every year. Over the north Indian Ocean, 2-3 severe cyclonic storms form out of total 5-6 cyclonic storms

How many cyclones cross different coastal states of India?

The frequencies of cyclonic storms crossing different coastal states of India during 1891-2006 are shown in the figure below. The frequency of severe cyclonic storms is maximum for Andhra Pradesh while that of cyclone is maximum for Orissa. Considering west coast only, Gujarat is most vulnerable.



Which is the most intense tropical cyclone on record?

Typhoon Tip in the Northwest Pacific Ocean on 12 October, 1979 was measured to have a central pressure of 870 hPa and estimated surface sustained winds of 165 knots (85 m/s). Typhoon Nancy on 12 September, 1961 is listed in the best track data for the Northwest Pacific region as having an estimated maximum sustained winds of 185 knots (95 m/s) with a central pressure of 888 hPa. However, it is now recognized that the maximum sustained winds estimated for typhoons during the 1940s to 1960s were too strong and that the 95 m/s (and numerous 83 to 93 m/s reports) is somewhat too high.

Note that Hurricane Gilbert's 888 hPa lowest pressure (estimated from flight level data) in mid September, 1988 is the most intense [as measured by lowest sea level pressure] for the Atlantic basin, it is almost 20 hPa weaker (higher) than the above Typhoon Tip of the Northwest Pacific Ocean.

While the central pressures for the Northwest Pacific typhoons are the lowest globally, the North Atlantic hurricanes have provided sustained wind speeds possibly comparable to the Northwest Pacific. From the best track database, both Hurricane Camille (1969) and Hurricane Allen (1980) have winds that are estimated to be 165 knots (85 m/s). Measurements of such winds are inherently going to be suspect as instruments often are completely destroyed or damaged at these speeds.

Orissa super cyclone, 1999 which crossed Orissa coast near Paradip on 29th October, 1999 was the most intense cyclonic storm over north Indian Ocean in the recorded history of the region. The estimated sustained maximum surface wind speed was about 140 knots at the time of landfall and lowest estimated central pressure was 912 hPa.

A few cyclones that have originated over the Bay of Bengal have reached the intensity of Super Cyclones and have caused great devastations to life and property. The estimates of maximum sustained winds of these systems are estimated from satellite imageries. The list of very intense Cyclones in the Bay of Bengal since 1990 is given below.

.Place of landfall	Date of landfall	Maximum sustained winds (kmph) - estimated on the basis of satellite imageries
Chittagong	13 November, 1970	224
Chirala, Andhra Pradesh	19 November, 1977	260
Rameshwaram	24 November 1978	204
Sriharikota	14 November, 1984	213
Bangla Desh	30 November, 1988	213
Kavali, Andhra Pradesh	9 November, 1989	235

Machlipatnam, AP	9 May ,1990	235
Chittagong	29 April, 1991	235
Teknaf (Myanmar)	2 May, 1994	204
Teknaf	19 May, 1997	235
Paradip, Orissa	29 October, 1999	260
89.8^0E, Bangladesh	15 November, 2007	220
16.0^0N, Myanmar	02 May, 2008	200

Which are the largest and smallest tropical cyclones on record?

Typhoon Tip had gale force winds 34 knots (17 m/s), which extended out for 1100 km in radius in the Northwest Pacific on 12 October, 1979. Tropical Cyclone Tracy had gale force winds that only extended 50 km radius when it struck Darwin, Australia, on 24 December,1974.

Considering north Indian Ocean, Orissa super cyclone of October, 1999 and the cyclone, 'Ogni' were the largest and smallest cyclones during 1891-2007.

Which tropical cyclone over north Indian Ocean have caused the most deaths and most damage?

The death toll in the infamous Bangladesh Cyclone of 1970 has had several estimates, some wildly speculative, but it seems certain that at least 300,000 people died from the associated storm tide [surge] in the low-lying deltas.

Why there are fewer cyclones over the Arabian Sea as compared to the Bay of Bengal?

Cyclones that form over the Bay of Bengal are either those develop insitu over southeast Bay of Bengal and adjoining Andaman Sea or remnants of typhoons over Northwest Pacific and move across south China sea to Indian Seas. As the frequency of typhoons over Northwest Pacific is quite high (about 35 % of the global annual average), the Bay of Bengal also gets its increased quota.

The cyclones over the Arabian Sea either originate insitu over southeast Arabian Sea (which includes Lakshadweep area also) or remnants of cyclones from the Bay of Bengal that move across

south peninsula. As the majority of Cyclones over the Bay of Bengal weaken over land after landfall, the frequency of migration into Arabian Sea is low.

In addition to all the above the Arabian Sea is relatively colder than Bay of Bengal and hence inhibits the formation and intensification of the system.

Why there are very few Tropical Cyclones during southwest monsoon season?

The southwest monsoon is characterized by the presence of strong westerly winds in the lower troposphere (below 5 km) and very strong easterly winds in the upper troposphere (above 9 km) .This results in large vertical wind shear. Strong vertical wind shear inhibits cyclone development.

Also the potential zone for the development of cyclones shifts to North Bay of Bengal during southwest monsoon season. During this season, the low pressure system upto the intensity of depressions form along the monsoon trough, which extends from northwest India to the north Bay of Bengal. The Depression forming over this area crosses Orissa – West Bengal coast in a day or two. These systems have shorter oceanic stay which is also one of the reasons for their non-intensification into intense cyclones.

What is the life period of cyclones? Which tropical cyclone lasted the longest?

Life period of a Tropical Cyclone over the north Indian Ocean is 5-6 days. It will have hurricane intensity for 2-4 days as against 6 days of global average. Life period of the longest lived Tropical cyclone in Indian seas is 14 days (2^{nd} -15^{th} Nov, 1886 & 16^{th} - 29^{th} Nov, 1964). Hurricane/Typhoon John lasted 31 days as it traveled both the Northeast and Northwest Pacific basins during August and September, 1994. (It formed in the Northeast Pacific, reached hurricane force there, moved across the dateline and was renamed Typhoon John, and then finally recurved back across the dateline and renamed Hurricane John again.) Hurricane Ginger was a tropical cyclone for 28 days in the North Atlantic Ocean back in 1971. It should be noted that prior to the weather satellite era (1961) many tropical cyclones' life cycles could be underestimated.

How are Tropical Cyclones monitored by IMD?

IMD has a well-established and time-tested organization for monitoring and forecasting tropical cyclones. A good network of meteorological observatories (both surface and upper air) is operated by IMD, covering the entire coastline and islands. The conventional observations are supplemented by observational data from automatic weather stations (AWS), radar and satellite systems. INSAT

imagery obtained at hourly intervals during cyclone situations has proved to be immensely useful in monitoring the development and movement of cyclones.

How is cyclone monitored by satellite technique ?

The satellite technique can be used to find out the centre and intensity of the system. It can also be used to find out various derived parameters which are useful for monitoring and prediction of the cyclones and associated disastrous weather.

Dvorak's technique based on pattern recognition in the cloud imagery based on satellite observation is used to determine the intensity of cyclonic storm. For this purpose a T. No. where T stands for tropical cyclone is assigned to the system. This scale of T Nos. varies from T 1.0 to T 8.0 at the interval of 0.5. The T 2.5 corresponds to the intensity of a cyclonic storm. The detailed classification of cyclonic disturbances based on above technique is given below:

"T" CLASSIFICATION OF CYCLONIC STORM AND

CORRESPONDING WIND SPEED AND PRESSURE DEFECT (?P)

T. Number/ C.I. Number	Classification of Cyclonic Disturbance	Wind speed in Knots	Wind speed In Kmph	? P	Wind criteria in Knots	Wind criteria in Kmph
T1.0	L				?17	?31
T1.5	D	25	46.3		17-27	31-49
T2.0	DD	30	55.6	4.5	28-33	50-61
T2.5	CS	35	64.9	6.1	34-47	62-88
T3.0		45	83.4	10.0		
T3.5	SCS	55	101.9	15.0	48-63	89-117
T4.0	VSCS	65	120.5	20.9	64-119	119-221
T4.5		77	142.7	29.4		
T5.0		90	166.8	40.2		
T5.5		102	189.0	51.6		
T6.0		115	213.1	65.6		
T6.5	SuCS	127	235.4	80.0	120 AND	222 AND

					ABOVE	ABOVE
T7.0		140	259.5	97.2		
T7.5		155	287.3	119.1		
T8.0		170	315.1	143.3		

What is the utility of Radar in cyclone monitoring ?

The radar can be utilized to find out the location of the cyclonic storm more accurately when the system comes within radar range. In addition it can find out convective cloud cluster, wind distribution, rainfall rate etc.

What is the present network of Cyclone Detection Radars?

A network of conventional Cyclone Detection Radars (CDRs) has been established at Kolkata, Paradip, Visakhapatnam, Machilipatnam, Chennai and Karaikal along the east coast and Goa, Cochin, Mumbai and Bhuj along the west coast. These conventional radars are being phased out and replaced by Doppler Weather Radars (DWRs). DWR have already been installed and made operational at Chennai, Kolkata, Visakhapatnam and Machlipatnam. An indigenously developed DWR Radar by Indian Space Research Organisation (ISRO) has been installed at Sriharikota.

It is proposed to replace all the conventional radars by DWRs during the next 3-4 years.

What are the basic differences between conventional analog type of Cyclone Detection Radar and the Doppler Weather Radar?

While conventional weather radar can look deeper into a weather system to provide information on intensity rain-rate, vertical extent, the capability to probe internal motion of the hydrometers and hence to derive information on velocity and turbulence structure has become available only with the advent of Doppler Weather Radar (DWRs) which provide vital information on radial velocity from which

wind field of a tropical disturbance in the reconnaissance area of DWR can be derived. In addition to above, a number of derived parameters useful for cyclone monitoring and prediction are also available from DWR.

What are the causes of disaster during cyclone?

The dangers associated with cyclonic storms are generally three fold.

i. Very heavy rains causing floods.

ii. Strong wind.

iii. Storm surge.

Let us discuss each separately:

(i) The rainfall associated with a storm vary from storm to storm even with the same intensity. Record rainfall in a cyclonic storm has been as low as trace to as high as 250 cms. It has been found that the intensity of rainfall is about 85 cms/day within a radius of 50 kms and about 35 cms/day between 50 to 100 kms from the centre of the storm. Precipitation of about 50 cm/day is quite common with a C.S. This phenomenal rain can cause flash flood.

(ii) The strong wind speed associated with a cyclonic storm. (60-90 kmph) can result into some damage to kutcha houses and tree branches likely to break off. Winds of a severe Cyclonic storm (90-120 kmph) can cause uprooting of trees, damage to pucca houses and disruption of communications. The wind associated with a very severe Cyclonic storm and super cyclonic storm can uproot big trees, cause wide spread damages to houses and installations and total disruption of communications. The maximum wind speed associated with a very severe Cyclonic storm that hit Indian coast in the past 100 years was 260 kmph in Oct., 1999 (Paradeep Super cyclone).

(iii) The severest destructive feature of a tropical storm is the storm surge popularly called tidal waves. The costal areas are subjected to storm surge and is accentuated if the landfall time coincides with that of high tides. This is again more if the sea bed is shallow. Storm surge as high as 15 to 20 ft. may

occur when all the factors contributing to storm surge are maximum. This storm tide inundates low lying coastal areas which has far reaching consequences apart from flooding. The fertility of land is lost due to inundation by saline water for a few years to come.

When does a coastal station start experiencing bad weather associated with a Cyclone?

Coasts come under the influence of bad weather in the form of heavy rain, gale winds (exceeding 65 kmph) when the cyclone moves closer to the coast within 200km. Heavy rainfall generally commences about 9-12 hours before cyclone landfall. Gale force winds commence about 6-9 hours in advance of cyclone landfall. Maximum storm surge may appear at or near the landfall time.

What is the amount of rainfall expected during a cyclone? Which sector gets more rainfall? What is the impact of heavy rainfall ?

Intensive Rainfall occurs to the left of the Cyclone. Maximum rainfall occurs close to the centre of the storm. Secondary maximum of rainfall occurs 2º away from Primary maximum to the right of the storm centre. Slow moving/big size cyclones give more rainfall, whereas, fast moving/small size ones give less rainfall. More than 90% of rainfall is limited within 200 Km radius of the storm. Extensive rainfall occurs in the left forward sector for westward moving system and forward sector for northward moving system and right forward sector for those re-curving to east and northeast.

The governing factors for rainfall distribution and intensity are intensity, speed and size of the storm and local effects such as topography and orientation of the coast.

What are the largest rainfalls associated with tropical cyclones over north Indian Ocean?

The rainfall can vary from trace/ nil rainfall when the system moves skirting the coast to maximum rainfall upto 50-60 cm per day. In the recent super cyclone which crossed Orissa coast near Paradip on 29th October 1999, Paradip recorded 24 hr cumulative rainfall of about 52 cm at 0830 IST of 30th October 1999.

What may be the wind speed in most severe storm?

The wind speed may be as high as 300 kmph.

What is the wind speed at the centre of a storm? What is weather there?

Nearly calm wind with fair weather prevails at the centre of the storm.

How is the damage that cyclones cause related with wind ?

The amount of damage does not increase linearly with the wind speed. Instead, the damage produced increases exponentially with the winds.

Which sector of the cyclone experiences strongest winds?

In general, the strongest winds in a cyclone are found on the right side of the storm. The "right side of the storm" is defined with respect to the storm's motion: if the cyclone is moving to the west, the right side would be to the north of the storm; if the cyclone is moving to the north, the right side would be to the east of the storm, etc. The strongest wind on the right side of the storm is mainly due to the fact that the motion of the cyclone also contributes to its swirling winds. A cyclone with a 145 kmph winds while stationary would have winds up to 160 kmph on the right side and only 130 kmph on the left side if it began moving (any direction) at 16 kmph. While writing the cyclone warning bulletins, this asymmetry is taken into consideration.

For tropical cyclones in the Southern Hemisphere, these differences are reversed: the strongest winds are on the left side of the storm. This is because the winds swirl clockwise south of the equator in tropical cyclones.

What causes each cyclone to have a different maximum wind speed for a given minimum sea-level pressure?

The basic horizontal balance in a tropical cyclone above the boundary layer is between the sum of the Coriolis 'acceleration' and the centripetal 'acceleration', balanced by the horizontal pressure gradient force. This balance is referred to as *gradient balance*, where the Coriolis 'acceleration' is defined as the horizontal velocity of an air parcel, **v**, times the Coriolis parameter, **f**. Centripetal 'force' is defined as the acceleration on a parcel of air moving in a curved path, directed toward the centre of curvature of the path, with magnitude $\mathbf{v^2/r}$, where **v** is the horizontal velocity of the parcel and **r** the radius of curvature of the path. The centripetal force alters the original two-force geostrophic balance and creates a non-geostrophic gradient wind. The reason that different peak winds can result in different central pressures is caused by the fact that the radius, **r**, of the peak wind varies. A storm with 40 m/s peak winds with a 100 km RMW will have a much lower pressure drop than one with a 25 km RMW.

Why do very severe cyclone or hurricane force winds start at 64 knots ?

In 1805-06, Commander Francis Beaufort RN (later Admiral Sir Francis Beaufort) devised a descriptive wind scale in an effort to standardize wind reports in ship's logs. His scale divided wind speeds into 14 Forces (soon after pared down to thirteen) with each Force assigned a number, a common name, and a description of the effects such a wind would have on a sailing ship. And since the worst storm an Atlantic sailor was likely to run into was a hurricane that name was applied to the top Force on the scale.

Beaufort Wind Scale	
Force 0	Calm
Force 1	Light Air
Force 2	Light Breeze
Force 3	Gentle Breeze
Force 4	Moderate Breeze
Force 5	Fresh Breeze
Force 6	Strong Breeze
Force 7	Near Gale
Force 8	Gale
Force 9	Strong Gale
Force 10	Storm
Force 11	Violent Storm
Force 12	Hurricane

During the 19th Century, with the manufacture of accurate anemometers, actual numerical values were assigned to each Force level, but it wasn't until 1926 (with revisions in 1939 and 1946) that the International Meteorological Committee (predecessor of the WMO) adopted a universal scale of wind speed values. It was a progressive scale with the range of speed for Forces increasing as you go higher. Thus Force 1 is only 3 knots in range, while the Force 11 is eight knots in range. So Force 12 starts out at 64 knots (74 mph, 33 m/s).

There is nothing magical in this number, and since hurricane force winds are a rare experience chances are the committee which decided on this number didn't do so because of any real observations during a hurricane. Indeed the Smeaton-Rouse wind scale in 1759 pegged hurricane force at 70 knots (80 mph, 36 m/s). Just the same, when a tropical cyclone has maximum winds of approximately these speeds we do see the mature structure (eye, eyewall, spiral rainbands) begin to form, so there is some utility with setting hurricane force in this neighborhood.

What is a Storm Surge?

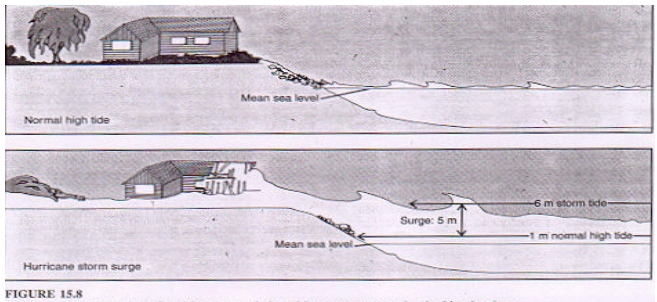


FIGURE 15.8
A hurricane storm surge produced by strong winds and low pressure associated with a hurricane approaching a coastal area. [After Michael D. Morgan et al., *Environmental Science: Managing Biological and Physical Resources*. Copyright © 1993 Wm. C. Brown Communications, Inc., Dubuque, Iowa.]

Storm Surge is an abnormal rise of sea level as the cyclone crosses the coast. Sea water inundates the coastal strip causing loss of life, large scale destruction to property & crop. Increased salinity in the soil over affected area makes the land unfit for agricultural use for two or three seasons.

Storm surge depends on intensity of the cyclone (Maximum winds and lowest pressure associated with it and Coastal bathymetry (shallower coastline generates surges of greater heights).

In which direction of a storm the surge will appear?

The on shore wind gives rise to storm surge. Thus the forward right sector of a storm gives rise to storm surge.

What is storm tide?

The storm tide is the combination of storm surge and the astronomical tide

What is the interaction of astronomical tide with storm surge?

In general one may expect that if there is a storm surge of x metres and tidal wave of y metres then during high tide total surges would be x+y and during low tide x-y. But, it is found that there is an interaction of storm surge with astronomical tide, and during high tide time the total surge is little less than x+y and during low tide time it is little more than x-y.

What are the disaster potential of Storm Surge?

Disaster potential due to cyclones is due to high storm surges occurring at the time of landfall. The storm surges are by far the greatest killers in a cyclone. as sea water inundates low lying areas of the coastal regions causing heavy floods, erosion of beaches and embankments, damage to vegetation and reducing soil fertility. Flooding due to storm surges pollute drinking water sources resulting in shortage of drinking water and causing out-break of epidemics, mostly water borne diseases Very strong winds (Gales) may cause uprooting of trees, damage to dwellings, overhead installations, communication lines etc., resulting in loss of life and property. Past records show that very heavy loss of life due to tropical cyclones have occurred in the coastal areas surrounding the Bay of Bengal. Cyclones are also often accompanied by very intense & heavy precipitation (exceeding 40-50 cm in a day or about 10cm or more per hour in some places)

What is the vulnerability our coastline from the point of view of storm surge potential?

Entire Indian coast can be categorized into 4 zones

- Very high risk zones (Surge height > 5m)
- High risk Zone (Surge height between 3-5m)
- Moderate risk zone (Surge height between 1.5 to 3m)
- Minimal risk zone (Surge height < 1.5m)

Accordingly

- The coastal areas and off-shore islands of Bengal and adjoining Bangladesh are the most storm-surge prone (~ 10-13m) – VHRZ
- East coast of India between Paradip and Balasore in Orissa (~ 5-7m) – VHRZ
- Andhra coast between Bapatla and Kakinada holding estuaries of two major rivers Krishna and Godavari (~ 5-7m) – VHRZ
- Tamilnadu coast between Pamban and Nagapattinam (~ 3-5m) – HRZ
- Gujarat along the west coast of India (~ 2-3m) -MRZ

Can we predict storm surge?

The storm surge is predicted by IMD using nomograms and dynemic model developed by IIT, Delhi. Both these models taken into consideration different characteristics, the cyclones and the coastal bathymetry to predict the storm surge.

Which tropical cyclone has produced the highest storm surge?

The Bathurst Bay Hurricane, also known as Tropical Cyclone Mahina, struck Bathurst Bay, Australia in 1899. It produced a 13 m (about 42 ft) surge, but other contemporary accounts place the surge at 14.6 m (almost 48 ft). Considering cyclones over north Indian Ocean, cyclone of 1970 has produced maximum storm surge of 13 metres in recent years. Some of the significant storm surges (metres) over the region are mentioned below.

Hooghly river (WB), October, 1737 : 13

Contai (WB), October, 1864 : 10-13

Bangladesh cyclone, November, 1970 : 13

Paradip, Orissa,October, 1971 : 4-5

Balasore Orissa, May, 1989 : 3-6

Orissa Super Cyclone, October, 1999 : 5-6

What is the damage potential of a deep depression (28 – 33 knots) and what are the suggested actions?

Structures: Minor damage to loose/ unsecured structures **Communication & power:**

Road/Rail: Some breaches in Kutcha road due to flooding

Agriculture: Minor damage to Banana trees and near coastal agriculture due to salt spray. Damage to ripe paddy crops

Marine Interests: Very rough seas. Sea waves about 4-6 m high.

Coastal Zone: Minor damage to Kutcha embankments

Overall Damage Category: Minor

Suggested Actions: Fishermen advised not to venture into sea

What is the damage potential of a cyclonic storm (34-47 knots or 62 to 87 kmph) and what are the suggested actions?

Structures: Damage to thatched huts

Communication and power: Minor damage to power and communication lines

due to breaking of tree branches.

Road/Rail: Major damage to Kutcha and minor damage to Pucca roads.

Agriculture: Some damage to paddy crops, Banana, Papaya trees and orchards.

Marine Interests: High to very high sea waves about 6-9 m high.

Coastal Zone: Sea water inundation in low lying areas after erosion of Kutcha embankments

Overall Damage Category: Minor to Moderate

Suggested Actions: Fishermen advised not to venture into sea

What is the damage potential of a severe cyclonic storm 48-63 Knots (88-117 Kmph) and what are the suggested actions?

Structures: Major damage to thatched houses / huts. Roof tops may blow off. Unattached metal sheets may fly.

Communication and power: Minor damage to power and communication lines.

Road/Rail: Major damage to Kutcha and some damage to Pucca roads. Flooding of escape routes.

Agriculture: Breaking of tree branches, uprooting of large avenue trees.

Moderate damage to Banana and Papaya trees: Large dead limbs blown from trees.

Marine Interests: Phenomenal seas with wave height 9-14 m. Movement in motor boats unsafe.

Coastal Zone: Major damage to coastal crops. Storm surge upto 1.5m (area specific) causing damage to embankments/ salt pans. Inundation upto 5 Km in specific areas.

Overall Damage Category: Moderate

Suggested Actions: Fishermen advised not to venture into sea. Coastal hutment dwellers advised to move to safer places. Other people in the affected areas to remain indoors.

What is the damage potential of a very severe cyclonic storm (64-90 Knots or 118-167 Kmph) and what are the suggested actions?

Structures: Total destruction of thatched houses/ extensive damage to Kutcha houses. Some damage to Pucca houses. Potential threat from flying objects.

Communication and power: Bending/ uprooting of power and communication poles.

Road/Rail: Major damage to Kutcha and Pucca roads. Flooding of escape routes. Minor disruption of railways, overhead power lines and signaling systems.

Agriculture: Widespread damage to standing crops plantations, orchards, falling of green coconuts and tearing of palm fronds Blowing down bushy trees like mango.

Marine Interests: Phenomenal seas with wave heights more than 14m. Visibility severely affected. Movement in motor boats and small ships unsafe.

Coastal Zone: Storm surge up to 2 m, Inundation up to 10 Km in specific areas. Small boats, country

crafts may get detached from moorings.

Overall Damage Category: Large

Suggested Actions: Fishermen not to venture into sea. Evacuation from coastal areas needs to be mobilized. People advised to remain indoors. Judicious regulation of rail and road traffic needed.

What is the damage potential of a very severe cyclonic storm (91-119 Knots or 168-221 Kmph) and what are the suggested actions?

Structures: Extensive damage to all types Kutcha houses, some damage to old badly managed Pucca structures. Potential threat from flying objects.

Communication and power: Extensive uprooting of power and communication poles.

Road/Rail: Disruption of rail / road link at several places.

Agriculture: Extensive damage to standing crops plantations, orchards. Blowing down of Palm and Coconut trees. Uprooting of large bushy trees.

Marine Interests: Phenomenal seas with wave heights more than 14m. Movement in motor boats and small ships not advisable.

Coastal Zone: Storm surge up to 2 – 5 m, Inundation may extend up to 10-15 Km over specific areas. Large boats and ships may get torn from their moorings, country crafts may get detached from moorings

Overall Damage Category: Extensive

Suggested Actions: Fishermen not to venture into sea. Evacuation from coastal areas essential. Diversion / suspension of rail traffic may be required.

What is the damage potential of a super cyclonic storm 120 Knots (222 Kmph) & above? What are the suggested actions?

Structures: Extensive damage to non-concrete residential and industrial building. Structural damage to concrete structures. Air full of large projectiles.

Communication and power: Uprooting of power and communication poles. Total disruption of communication and power supply.

Road/Rail: Extensive damage to Kutcha roads and some damage to poorly repaired pucca roads. Large scale submerging of coastal roads due to flooding and sea water inundation. Total disruption of railway and road traffic due to major damages to bridges, signals and railway tracks. Washing away of rail / road links at several places.

Agriculture: Total destruction of standing crops / orchards, uprooting of large trees and blowing away of palm and coconut crowns, stripping of tree barks.

Marine Interests: Phenomenal seas with wave heights more than 14m. All shipping activity unsafe.

Coastal Zone: Extensive damage to port installations. Storm surge more than 5m, Inundation up to 40 Km in specific areas and extensive beach erosion. All ships torn from their moorings. Flooding of escape routes.

Overall Damage Category: Catastrophic

Suggested Actions: Fishermen not to venture into sea. Large scale evacuations needed. Total stoppage of rail and road traffic needed in vulnerable areas.

What is the normal movement of a Tropical Cyclone?

Tropical Cyclones move as a whole. They casually move west-northwestwards or northwestwards in the northern hemisphere. The average speed is 15-20 kmph (360-480 km per day). They may change their direction of movement towards north. During this change their speed of movement decreases to 10 kmph or even less. A larger fraction of such storms later turn towards northeast and move northeastwards very fast at a speed of 25 kmph or more.

What are fast and slow moving cyclones?

When the speed of movement is 10-14 kmph, it is called as slow moving cyclone. It is called as moderately moving cyclone, if the speed of movement is 15-25 kmph. If the speed of movement is more than 25 kmph, is called as fast moving cyclone.

How track prediction is done in IMD ?

Various Techniques are available for Track Prediction of the storm as mentioned below:

I. Methods based on climatology, persistence and both Climatology & Persistence (CLIPER)

II. Synoptic Techniques – Empirical Techniques

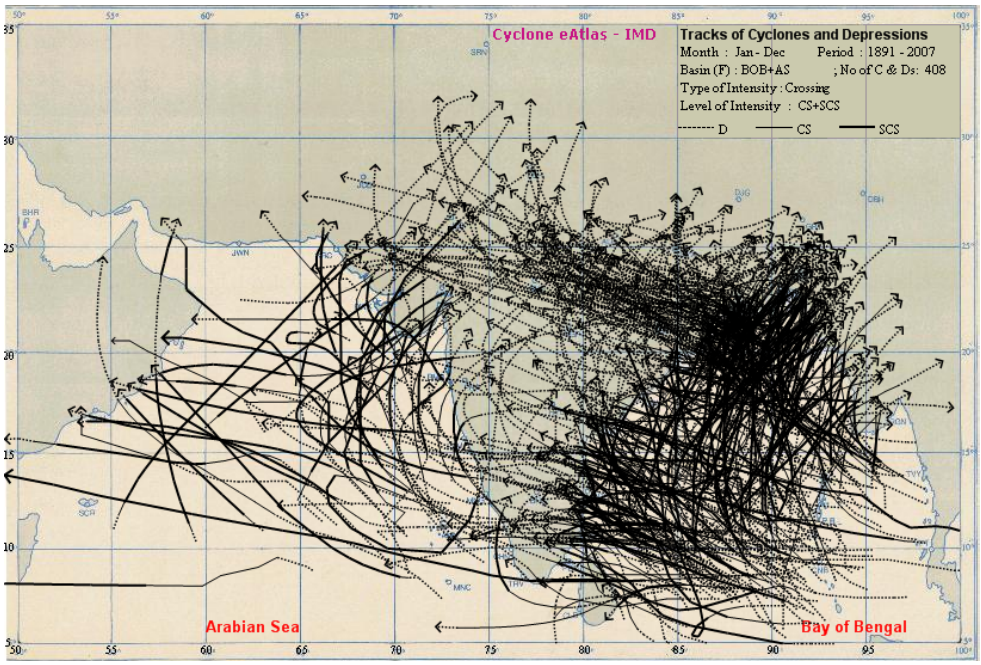
III. Satellite Techniques

IV. Statistical Techniques using climatology, persistence and synoptic

V. Analogue Techniques

VI. Numerical weather prediction models

The tracks of the cyclonic storms over north India ocean during 1891-2007 are shown below:



What are the numerical weather prediction models used operationally for Tropical Cyclone track Prediction and storm surges in IMD?

- T-254 model of NCMRWF, MM5 mesoscale model
- Quasi-Lagrangian Limited Area Model (QLM) for track prediction
- Weather Research and Forecast (WRF) mesoscale model for intensification and track prediction
- Prediction Models of IIT – Delhi and NIOT Chennai for Storm Surge rediction

In addition to above, IMD forecasters make use of various forecasts available from international NWP models like BCBCMRF, UKMET and COLA etc.

What is our accuracy of landfall prediction?

Probability of correct forecast decreases with increasing forecast validity period. Mean forecast errors for 12, 24, 48 and 72 hours are about 50, 140, 300 and 500 km respectively, which are comparable to corresponding figures of other centres like National Hurricane Centre, Miami, which monitor Atlantic Hurricanes; Typhoon Warning Centre, Tokyo, which monitors Typhoons of Northwest Pacific etc.

How does IMD predict intensity of the cyclone ?

Subjective techniques like Climatology, Synoptic and Satellite (Dvorak) techniques and radar techniques are used. Though the performance of NWP models in intensity prediction is not satisfactory, they provide valuable guidance in intensity prediction also.

What is the role of upper tropospheric westerly trough ?

An Upper tropospheric westerly trough is important for tropical cyclone forecasting as they can force large amounts of vertical wind shear over tropical disturbances and tropical cyclones which may inhibit their strengthening. There are also suggestions that these troughs can assist tropical cyclone genesis and intensification by providing additional forced ascent near the storm centre and/or by allowing for an efficient outflow channel in the upper troposphere. The location of this trough and its intensity can also influence the movement of the storm and hence can be used for cyclone track forecasting.

Why Tropical Cyclones weaken over land after landfall ?

After just a few hours, a tropical cyclone over land begins to weaken rapidly because the storm lacks the moisture and heat sources that the ocean provided. This depletion of moisture and heat hurts the tropical cyclone's ability to produce thunderstorms near the storm centre. Without this convection the cyclone cannot survive.

However, there are instances like Orissa super cyclone of October 1999, which maintained its intensity of cyclonic storm even 24 hours after landfall. During this period, it remained practically stationary over coastal Orissa.

Doesn't the friction over land kill tropical cyclones?

No, during landfall, the increased friction over land acts - somewhat contradictory - to both decrease the sustained winds and also to increase the gusts felt at the surface. The sustained winds are reduced because of the dampening effect of larger roughness over land (i.e. bushes, trees and houses over land versus a relatively smooth ocean). The gusts are stronger because turbulence increases and acts to bring faster winds down to the surface in short (a few seconds) bursts.

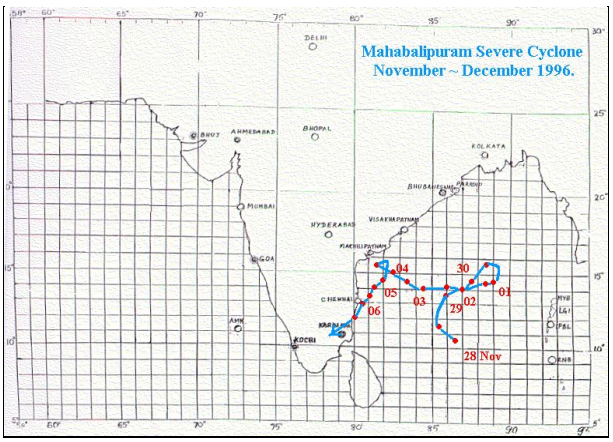
What are the abnormal characteristics associated with Tropical Cyclones?

Majority of Tropical Cyclones are associated with some sort of abnormal behavior such as

- Rapidly changing trends in motion and intensity
- Remaining quasi-stationary close to landfall

- Development or intensification close to a populated coastline
- Approaching a vulnerable coastline at an acute angle so that even minor forecast errors introduce large landfall uncertainties
- Threatening the coastal community during high pitch of seasonal activity such as harvesting, festivals, holidays etc.

Two examples of such cyclones are shown below.



What is the organizational set up in IMD for Cyclone forecasting and Warning?

The Cyclone Warning Organization in India has a 3-tier system to cater to the needs of the maritime States. These are : Cyclone Warning Division set up at IMD Head Quarters to co-ordinate and supervise cyclone warning operations in the country and to advise the Govt. at the apex level; Area Cyclone Warning Centres at Chennai, Mumbai and Kolkata and Cyclone Warning Centres at Visakhapatnam, Ahmedabad and Bhubaneswar. The cyclone warning work is also supervised and coordinated by the Forecasting Division at Pune.

What are the different bulletins issued by IMD in connection with the cyclone?

1. Weather and Sea area bulletins.
2. Bulletins for Indian Navy.
3. Bulletins for Departmental Exchange.
4. Port Warnings
5. Fisheries warnings
6. Four Stage Warnings
7. Bulletins for AIR

8. Bulletins for Press
9. Coastal bulletins
10. Warnings to Designated/ Registered Officials
11. Aviation Warnings

What is 4-stage warning system for Tropical Cyclones?

Expectations of Disaster Managers are longer lead time and improved accuracy of landfall forecast. But the present state of art has limitations to make the above requirements go hand in hand. Lead time depends on the formation and duration of cyclone itself which may vary considerably from one cyclone to another. However, since pre-monsoon cyclone season of 1999, IMD introduced a 4-Stage warning system to issue cyclone warnings to the disaster managers. They are as follows:

(1) **Pre-Cyclone Watch**

Issued when a depression forms over the Bay of Bengal irrespective of its distance from the coast and is likely to affect Indian coast in future. The pre-cyclone watch is issued by the name of Director General of Meteorology and is issued at least 72 hours in advance of the commencement of adverse weather. It is issued at least once a day.

(2) **Cyclone Alert**

Issued atleast 48 hours before the commencement of the bad weather when the cyclone is located beyond 500 Km from the coast. It is issued every three hours.

(3) **Cyclone Warning**

Issued at least 24 hours before the commencement of the bad weather when the cyclone is located within 500 Km from the coast. Information about time /place of landfall are indicated in the bulletin. Confidence in estimation increases as the cyclone comes closer to the coast

(4) **Post landfall outlook**

It is issued 12 hours before the cyclone landfall, when the cyclone is located within 200 Km from the coast. More accurate & specific information about time /place of landfall and associated bad weather indicated in the bulletin. In addition, the interior distraction is likely to be affected due to the cyclone are warned in this bulletin.

How frequently IMD issues these bulletins?

When cyclone is beyond the range of coastal cyclone detection radar, (more than 400 km away from coast), cyclone warnings are issued 6 times a day to air stations and each warning is broadcast at frequent intervals interrupting routine programme. When the cyclone comes within radar range and tracked by radar, cyclone warnings are issued every hour to air stations. During cyclone period, concerned air stations keep round the clock watch for broadcasting cyclone warnings.

Is there any order in mentioning the disastrous weather in the bulletin?

A certain order depending upon the intensity and proximity of the system to the coast will be observed during cyclone period while indicating the adverse weather.

In case of a cyclone expected to strike the coast in

- About 12 hrs: tidal wave / gales / heavy rain fall
- Next 12-24 hrs: gales / tidal wave / heavy rain fall
- About 24 hrs: rain / gales / tidal wave

What is port warning?

The strong winds and high seas pose dangers to port. Moreover if a storm is at high seas the ships moving out of the port may fall into danger. Therefore the port is informed accordingly and advised to hoist signals which can he seen by mariners both during day and night. There are eleven such signals. The significant features of this warning are as follows.

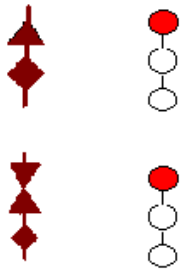
- Port officers are warned about disturbed weather likely to affect their Ports by IMD.
- On receipt of warnings, Port officials hoist appropriate visual signals so that they are visible from a distance.
- Ports are warned 5 to 6 times a day during period of cyclonic storm.
- Warning contains information about location, intensity, expected direction, expected landfall point and type of signal the Port should hoist.
- Uniform system of storm warning signals introduced from 1st April 1898.

There are different types of signals for different ports as mentioned below.

1. GENERAL SYSTEM : General Ports (eleven signals)
2. EXTENDED SYSTEM: Extended Ports (Six section signals + eleven signals)
3. BRIEF SYSTEM : Brief ports (III, IV, VII, X, XI signals)
4. MINOR PORTS : Special messages. No signals are hoisted.

PORT WARNINGS

Signal/ Flag No.		NAME	Symbols		Description
			Day	Night	
1.	Distant bad weather	DC1			Depression far at sea. Port NOT affected.
2.		DW2			Cyclone for at sea. Warning for vessels leaving port.
3.	Local bad weather	LC3			Port Threatened by local bad weather like squally winds.
4.		LW4			Cyclone at sea. Likely to affect the port later.
5.		D5			Cyclone likely to cross coast keeping port to its left
6.					Cyclone likely to cross coast keeping port to its

7.	Danger	D6			right.
		D7			Cyclone likely to cross coast over/near to the port.
8.	Great danger	GD8			Severe cyclone to cross coast keeping port to its left
9.		GD9			Severe cyclone to cross coast keeping port to its right
10.		GD10			Severe cyclone to cross coast keeping port to its right.
11.		XI			Communication failed with cyclone warning office.

W

hat are fishermen warning?

A fisherman warning is warning message for fishermen who ply on coastal areas or may go out at sea. Dangers to fisherman due to storm are strong winds and associated high seas, due to which fishing boats may capsize. Hence, the fishermen are issued warning when one of the following conditions of weather is expected along and off any coast

1. Strong off-shore and on-shore winds (or with appropriate direction), speed exceeding 45 kmph
2. Squally weather – frequent squalls with rain; or persistent type of strong gusty winds (>20kts; 36kmph) accompanied by rain.
3. Gales and
4. State of sea very rough or above (wave heights are four metres or more).

The warnings are disseminated to fishermen through

1. Port
2. Fisheries officials and
3. AIR broadcast daily three / four times in local language. The warnings are broadcast as a routine four times a day (morning (0600 hrs), mid-day, evening (1800 hrs) and mid-night) from the air stations in the local language. During a cyclonic storm, such warnings are covered in the cyclone bulletins sent to the air stations at hourly or 3 hourly intervals for frequent broadcast. The fisheries warnings issued in mid-day are incorporated in the 'general weather bulletin' by forecasting offices in maritime states.

The fishermen warning contains information about

1. Synoptic situation
2. Signals hoisted and
3. Advice not to go out in to the sea.

What is sea area bulletin?

- Issued by ACWC for deep sea
- Normally twice a day (based on 03 and 12 UTC
- Thrice a day in case of depression/ deep depression (additional bulletin based on 18 UTC)
- Six times a day in case of a cyclone. There is also provision of special bulletin.
- The bulletin contains significant system, expected weather, wind, state of sea, port warning etc.

What is coastal weather bulletin?

- Issued by area cyclone warning centre/ cyclone warning centre for coastal shipping
- Normally twice a day (based on 03 and 12 UTC
- Issued based on sea area bulletin
- Thrice a day in case of depression/ deep depression (additional bulletin based on 18 UTC)
- Six times a day in case of a cyclone. There is also provision of special bulletin
- The bulletin contains significant system, expected weather, wind, state of sea, port warning etc

What is the meaning of widespread /fairly wide spread/scattered/isolated rainfall?

The rainfall distribution as mentioned in the bulletin are based on following classification

DISTRIBUTION	NO. OF PLACES	DESCRIPTION
Isolated	One or two places	<25% of area gets rainfall
Scattered	A few places	(26 –50)% of area gets rainfall
Fairly Widespread	A many places	(51 – 75)% of area gets rainfall
Wide Spread	Most place	(76 – 100)% of area gets rainfall

What do you mean by heavy rainfall, very heavy rainfall and extremely heavy rainfall ?

The intensity of rainfall mentioned in the bulletin is based on the following criteria:

Descriptive term used	Rainfall amount in mm
No rain	0.0
Very light rain	0.1- 2.4
Light rain	2.5 – 7.5
Moderate rain	7.6 – 35.5
Rather heavy	35.6 – 64.4
Heavy rain	64.5 – 124.4
Very heavy rain	124.5 – 244.4

Extremely heavy rain	>244.5
Exceptionally heavy rain	When the amount is a value near about highest recorded rainfall at or near the station for the month or season. However, this term will be used only when the actual rainfall amount exceeds 12 cm.

How does IMD mention state of sea in the bulletins?

This is mentioned subjectively in plain language like rough sea, very rough sea etc. based on the prevailing wind over the sea surface as mentioned below.

Descriptive Term	Height Metres	Wind Speed Knots (Kmph)	Inbeaufort Scale
CALM (GLASSY)	0	0	0
CALM (RIPPLED)	0 - 0.1	1 - 3 (2 - 6)	1
SMOOTH (WAVELESS)	0.1 - 0.5	4 - 10 (7 - 19)	2 - 3
SLIGHT	0.5 - 1.25	11 - 16 (20 - 30)	4
MODERATE	1.25 - 2.5	17 - 21 (31 - 39)	5
ROUGH	2.5 - 4.0	22 - 27 (41 - 50)	6
VERY ROUGH	4.0 - 6.0	28 - 33 (52 - 61)	7
HIGH	6.0 - 9.0	34 - 40 (63 - 74)	8
VERY HIGH	9.0 - 14.0	41 - 63 (76 - 117)	9 - 11
PHENOMENAL	OVER 14	64 OR ABOVE (119 OR ABOVE)	12

What is meaning of the reference time mentioned in the bulletin ?

The meaning of different reference times mentioned in the bulletin are given below.

- EARLY HOURS 0000 - 0400 HRS. IST
- MORNING 0400 - 0800 HRS. IST
- FORENOON 0800 - 1200 HRS. IST
- AFTERNOON 1200 - 1600 HRS. IST

- EVENING 1600 - 2000 HRS. IST
- NIGHT 2000 - 2400 HRS. IST
- EARLY MORNING 0400 - 0600 HRS. IST
- AROUNDNOON 1100 - 1300 HRS. IST)

How are Cyclone Warnings disseminated ?

The different telecommunication channels used are as follows

- Landline
- T/P (Internal)
- Telex
- Telephone
- Telefax
- VHF/HFRT (Internal)
- Cyclone Warning Dissemination System (CWDS)
- Police Wireless
- AFTN (Aviation)
- Internet (e-mail)
- Websites
- Radio/TV network
- Interactive voice response system (IVRS)
- Mobile Phones

However, the Telex is being phased out by Department of Telecommunications, Govt. of India.

What are the bulletins available in the website? What is the website address ?

There are two cyclone related bulletins issued by Cyclone Warning Division, IMD, New Delhi. These are as follows.

i. Bulletin for Indian coast

ii. Regional Specialised Meteorological Centre (RSMC) bulletin

In, addition, the predicted track of the cyclone based on quasi-Lagrangian model (QLM) run by IMD. All these information/bulletins are available in the Cyclone Page of IMD's Web site (www.imd.gov.in)

What is IVRS ? How does it work ?

IVRS stands for interactive voice response system. The requests for weather information and forecasts from the general public are automatically answered by this system. For this purpose, the person has to dial a toll-free Number "18001801717" from anywhere in the country. This system has been installed at 26 Meteorological Centres/ Regional Meteorological Centres. The data on maximum & minimum temperatures and Rainfall for a large number of towns/cities are provided. The local weather forecasts of cities and multi-hazard warnings including cyclone warnings are also provided.

What is Cyclone Warning Dissemination System (CWDS)?

This is a unique scheme not tried anywhere in the world. The scheme has been extremely successful during the cyclones for last 24 years and gained considerable confidence of the public of this country.

- Designed by ISRO and implemented by IMD in the mid-eighties, the CWDS is used all these years to disseminate cyclone warnings effectively.
- Selective addressing (Separate messages for each district) is done by transmitting a digital code followed by the actual warning message
- Cyclone warnings are generated in English and other local languages (Tamil, Telugu, Oriya, Bengali, Marathi, Gujarathi etc)
- Though Radio/TV broadcast are for one and all, the messages through CWDS can be accessed only at centres equipped with a receiver and addressed specifically for receiving the message
- CWDS is one-way communication system and will be complimentary to other systems of cyclone warning dissemination. Facility of acknowledgement is available in the upgraded (Digital) version of CWDS
- The present CWDS network covers 252 stations spread over coastal areas of maritime districts along the east and e west coast
- Through World Bank assistance Govt. of Andhra Pradesh had installed 100 Digital CWDS receivers along Andhra Coast. For this purpose a digital up-linking station also functions at Chennai.

Who are the recipients of Cyclone Warnings?

Warnings are issued for general public, fishermen, farmers and different categories of users such as central and state government officials responsible for disaster mitigation and relief, industrial and other establishments located in the coastal areas, ports, coastal shipping, railways, aviation, transport, communication and power authorities.

How a common man gets information about a cyclonic storm?

Local AIR broadcast hourly (or more frequently) bulletins in local language as well as in Hindi and English. The bulletins give the location of the Cyclonic storm, its direction of movement, place and time of landfall and details of adverse weather expected over the areas likely to be affected by the storm. AIR, New Delhi issues bulletins thrice in a day giving similar information. Apart from that, the cyclone warning messages are sent to the collectors of the districts likely to be affected and the chief secretary of concerned state. The state Govt. takes necessary steps to inform the local population through their machinery such as police wireless etc. They make necessary arrangement for evacuation from coastal area and for removal of the population to other places.

On the event of any doubt about approach of a cyclonic storm to whom a common man can approach to get authentic information (in absence of relevant AIR bulletins)?

Normally all collectors of coastal districts (subjected to adverse weather due to cyclonic storm) are intimated by sending warning messages through fax. They in turn inform junior officers under their control to take necessary action. These informations will be therefore available with the state Govt. officials. More over if any one is having phone facilities he may contact nearest cyclone warning centre/ Area cyclone warning centre or Cyclone Warning Division at IMD Head Quarters, New Delhi to get most authentic information about storms over Bay of Bengal. Also one can take advantage of IVRS system to get latest information.

How does IMD keep liaison with State officials?

Area Cyclone Warning Centres (ACWCs) and Cyclone Warning Centres (CWCs) maintain liaison with the concerned state Governments in state and district levels on cyclone related activities. The cyclone warning bulletins are communicated to the Chief Secretary, Revenue Secretary, Special Relief Commissioner, State control room, State Disaster Management Authority and concerned district collectors every three hourly. In addition, the Chief Secretary is personally briefed by Director,

ACWC/CWC regularly. Before the cyclone season, ACWC/CWC organizes the precyclone preparedness meeting under the chairmanship of Chief Secretary where all the high state Govt. officials from various departments participate.

What are the devastations which can not be protected by a common man and has to be mentally prepared to accept the loss?

Inundations caused by storm surge, uprooting of trees and damage caused by that, flooding of low lying areas due to heavy rain and damage to houses and communication due to very strong winds.

How to understand that the cyclonic storm has weakened/moved away?

With the approach of a storm squally weather commences. On the other land the storm weakens or goes away from the station the /weather gradually improves. The rainfall decreases. the wind speed weakens and gradually sky clears. However one should be very careful about the situation when the centre of the storm technically known as the "eye" of the storm passes through the station. The station will first experience very severe weather with approaching cyclone. When the eye of the storm passes over the station the weather becomes practically fair with light winds and little or no clouds at all. During night stars may he visible. But after a lapse of few minutes (say 10-15 minutes) very severe weather again commences. This time the wind blows from exactly the opposite direction. A sharp change from very severe weather to fair weather may be an indication that the eye of the storm is approaching the station.

What are the pre-cyclone/during the cyclone/post cyclone responsibilities of a common man?

1. <u>Steps to be taken before the cyclone</u>

i. Check houses, secure loose tiles by cementing wherever necessary, repair doors and windows.

ii. Check the area around the house -remove dead or dying trees, anchor removable objects like lumber piles, loose bricks, garbage cans, sign-boards, loose zinc sheets etc.

iii. Keep some wooden boards ready so that glass windows can be boarded.

iv. Keep a hurricane Lantern filled with kerosene, flash light and enough dry cells.

v. Promptly demolish condemned buildings.

vi. Those who have radio sets should ensure that the radio is fully serviceable in the case of transistors an extra set of batteries should be kept handy.

2. <u>Steps to be taken during the cyclone.</u>

i. Keep your radio on and listen to latest weather warnings and advisories from the nearest All India Radio station. Pass the information to others.

ii. Avoid being misled by rumors. Pass only the. Official information you have got from the radio to others.

iii. Get away from low lying beaches or other locations which may be swept by high tides or storm waves. Leave sufficiently early before your way to high ground gets flooded. Do not delay and run the risk of being marooned.

iv. If your house is out of danger from high tides and flooding from the river, and it is well built, it is then probably the best place during weather and storm. However, please act promptly if asked to evacuate.

v. Be alert for high water in areas where streams of rivers may flood due to heavy rains.

vi. Board up glass windows or put storm shutters in place. Use good wooden planks Securely fastened. Make-shift boarding may do more damage than none at all. Provide strong suitable support for outside doors.

vii. If you do not have wooden boards handy paste paper strips on glasses to prevent splinters flying into the, house.

viii. Get extra food, specially things which can be eaten without cooking or with very little preparation. Store extra drinking water in suitable covered vessel.

ix. If you are in one of the evacuation areas, move your valuable articles to upper floors to minimise flood damage.

x. Have hurricane lantern, flash lights and/or other emergency light in working condition and keep them handy.

xi. Check on everything that might blow away or be torn loose. Kerosene tins, cans, agricultural implements, garden tools, road signs and other objects become weapon of destruction in strong winds. Remove them and store them in a covered room.

xii. Be Sure that a window or door can be opened on the lee side of the house i.e. the side opposite the one facing the wind.

xiii. Make provisions for children and adults requiring special diets.

xiv. If the centre of' ‘eye' of the storm passes directly over your place, there will be a lull in the wind and rain, lasting for half an hour or more. During this period stay in safe place. Make emergency repairs during the lull period if necessary, but remember that strong wind will return suddenly from the opposite direction, frequently with even greater violence.

(xv) Be calm. Your ability to meet emergency will inspire and help others.

3. <u>Steps to be taken after Cyclone.</u>

i. They should remain in shelters until informed by those in charge that they may return home.

ii. Any loose and dangling wire from the lamp post should be strictly avoided.

iii. People should keep away from disaster areas unless they are required to assist.

iv. Anti-social elements should be prevented from doing mischief and reported to the police.

v. Cars, buses lorries and carts should be driven carefully.

vi. The houses and dwellings should be cleared of debris.

vii. The losses should be reported to the appropriate authorities.

viii. Relatives should be promptly informed about the safety of persons in the disaster area.

How IMD coordinates with National Disaster Management Division (NDM) of the Ministry of Home Affairs?

IMD has established linkages/institutional arrangements with disaster management agencies both at the centre and in the states. During normal weather conditions two bulletins are transmitted to Control Room of National Disaster Management Division (NDM). In a case of depression develops over north Indian Ocean which has the potential to affect Indian coast, special bulletins at-least three times a day are issued to NDM. When the system intensifies into a cyclonic storm, the cyclone warning bulletins are every three hourly. At present 4 stage warning procedure as discussed earlier is followed for issuing bulletins to NDM Control Room. When the system weakens or not going to affect Indian coast, a dewarning message is also issued to NDM Control Room. The cyclone warning bulletins are also passed on to State Government Authorities/District Collectors who are in constant touch with Cyclone Warning Centres. The centres and local committees consisting of various departments dealing with disaster management issues meet at the time of crisis and take necessary follow up actions.

What is the role of IMD Tropical Cyclone management of north Indian Ocean Rim countries?

A Regional Specialized Meteorological Centre (RSMC) has been established at IMD, New Delhi. It is one of the six such centres recognized by the WMO under a global system for monitoring tropical cyclones. As an international commitment, through the WMO/ESCAP Panel on Tropical Cyclones, tropical cyclone advisories are issued by RSMC, New Delhi to the Panel Member countries during the tropical cyclones in the Bay of Bengal and the Arabian Sea. The other ESCAP Panel countries are Thailand, Myanmar, Bangladesh, Pakistan, Sri Lanka, Maldives and Oman.

What are the bulletins issued by RSMC, New Delhi?

RSMC New Delhi issues the following bulletins

- Tropical Weather Outlook for WMO/ESCAP Panel member countries
- Special Tropical Weather Outlook for WMO/ESCAP Panel member countries
- Tropical Cyclone Advisory for Panel member countries
- Tropical Cyclone Advisory for International Aviation

RSMC, New Delhi is also designated as Tropical Cyclone Advisory Centre (TCAC) and issues cyclone advisories for International Aviation as per the guidelines of ICAO. These advisories are issued every six hours based on observations at 0000, 0600, 1200 and 1800 UTC.

What is UTC? How do I tell at what time a satellite picture was taken?

UTC stands for **Universal Time Coordinated**, what used to be called Greenwich Mean Time (**GMT**) and Zulu Time (**Z**). This is the time at the Prime Meridian (0° Longitude) given in hours and minutes on a 24 hour clock. For example, 0000 UTC is 0530 hours IST. The Greenwich Royal Observatory at Greenwich, England (at 0° Longitude) was where naval chronometers (clocks) were set, a critical instrument for calculating longitude. This is why **GMT** became the standard for world time. Meteorologists have used **UTC** or **GMT** times for over a century to ensure that observations taken around the globe are taken simultaneously.

On most satellite pictures and radar images the time will be given as **UTC**, **GMT**, or **Z** time.

What is relation between kmph and knots (or m/s) ?

For winds:

1 mile per hour = 0.869 international nautical mile per hour (knot)

1 knot = 1.852 kilometers per hour

1 knot = 0.5144 meter per second

1 meter per second = 3.6 kilometers per hour

Why are tropical cyclones named?

Tropical cyclones are named to provide easy communication between forecasters and the general public regarding forecasts, watches, and warnings. Since the storms can often last a week or longer and that more than one can be occurring in the same basin at the same time, names can reduce the confusion about what storm is being described. The first use of a proper name for a tropical cyclone was by an Australian forecaster early in the 20th century. He gave tropical cyclone names "after political figures whom he disliked. By properly naming a hurricane, the weatherman could publicly describe a politician (who perhaps was not too generous with weather-bureau appropriations) as 'causing great distress' or 'wandering aimlessly about the Pacific.'" (Perhaps this should be brought back into use)

During World War II, tropical cyclones were informally given women's names by US Army Air Corp and Navy meteorologists (after their girlfriends or wives) who were monitoring and forecasting tropical cyclones over the Pacific. From 1950 to 1952, tropical cyclones of the North Atlantic Ocean were identified by the phonetic alphabet (Able-Baker-Charlie-etc.), but in 1953 the US Weather Bureau switched to women's names. In 1979, the WMO and the US National Weather Service (NWS) switched to a list of names that also included men's names.

The Northeast Pacific basin tropical cyclones were named using women's names starting in 1959 for storms near Hawaii and in 1960 for the remainder of the Northeast Pacific basin. In 1978, both men's and women's names were utilized.

The Northwest Pacific basin tropical cyclones were given women's names officially starting in 1945 and men's names were also included beginning in 1979. Beginning on 1 January 2000, tropical cyclones in the Northwest Pacific basin are being named from a new and very different list of names. The new names are Asian names and were contributed by all the nations and territories that are members of the WMO's Typhoon Committee. These newly selected names have two major differences from the rest of the world's tropical cyclone name rosters. One, the names by and large are not personal names. There are a few men's and women's names, but the majority are names of flowers, animals, birds, trees, or even foods, etc, while some are descriptive adjectives. Secondly, the names will not be allotted in alphabetical order, but are arranged by contributing nation with the countries being alphabetized.

The Southwest Indian Ocean tropical cyclones were first named during the 1960/1961 season.

The Australian and South Pacific region (east of 90E, south of the equator) started giving women's names to the storms in 1964 and both men's and women's names in 1974/1975.

The North Indian Ocean region tropical cyclones are being named since October 2004. The list of approved names of the cyclones over north Indian Ocean is given below:

List of approved names of tropical cyclones over the north Indian Ocean

WMO/ESCAP Panel **Member contributing the names**	**Column one**		**Column two**		**Column three**		**Column four**	
	Names	**Pron'**	**Names**	**Pron'**	**Names**	**Pron'**	**Names**	**Pron'**
B'desh	Onil	Onil	Ogni	Og-ni	Nisha	Ni-sha	Giri	Gi-ri
India	Agni	Ag'ni	Akash	Aakaa'sh	Bijli	Bij'li	Jal	Jal
Maldives	Hibaru	--	Gonu	--	Aila	--	Keila	--

Myanmar	Pyarr	Pyarr	Yemyin	Ye-myin	Phyan	Phyan	Thane	Thane
Oman	Baaz	Ba-az	Sidr	Sidr’	Ward	War’d	Murjan	**Mur’jaan**
Pakistan	Fanoos	Fanoos	Nargis	Nar gis	Laila	Lai la	Nilam	Ni lam
Sri Lanka	Mala	--	Rashmi	Rash’mi	Bandu	--	Mahasen	--
Thailand	Mukda	Muuk-dar	Khai Muk	Ki-muuk	Phet	Pet	Phailin	Pi-lin

Panel Member	**Column five**		**Column six**		**Column seven**		**Column eight**	
	Names	**Pron’**	**Names**	**Pron’**	**Names**	**Pron’**	**Names**	**Pron’**
B’desh	Helen	Helen	Chapala	Cho-po-la	Ockhi	Ok-khi	Fani	Foni
India	Lehar	Le’har	Megh	Me’gh	Sagar	Saa’gar	Vayu	Vaa’yu
Maldives	Madi	--	Roanu	--	Mekunu	--	Hikaa	--
Myanmar	Nanauk	Na-nauk	Kyant	Kyant	Daye	Da-ye	Kyarr	Kyarr
Oman	Hudhud	Hud’hud	Nada	N’nada	Luban	L’luban	Maha	M’maha
Pakistan	Nilofar	Ni lofar	Vardah	Var dah	Titli	Titli	Bulbul	**Bul bul**
Sri Lanka	Priya	--	Asiri	Aa’siri	Gigum	Gi’gum	Soba	--
Thailand	Komen	Goh-men	Mora	Moh-rar	***Phethai***	Pay-ti	Amphan	Um-pun

How can I nominate a new name for the list?

The names to be included in the list must meet some fundamental criteria. They should be short and readily understood when broadcast. Further the names must be culturally sensitive and not convey some unintended and potentially inflammatory meaning. Typically, over the historical record, about one storm each year causes so much death and destruction that its name is considered for retirement. The suggested name may be communicated to Director General of Meteorology, India Meteorological Department, Mausam Bhavan, Lodi Road, New Delhi-110003.

Can we tame a tropical Cyclone to reduce its damage potential?

Considering the huge energy potential of the Cyclones, all experiments in US under he Project "Storm Fury" to tame them have turned futile. The best solution is not to try to alter or destroy the tropical cyclones, but just learn to co-exist better with them. Since we know that coastal regions are vulnerable to the storms, enforce building codes that can have houses stand up to the force of the tropical cyclones. In this regard the Building Material Technology Promotion Council (BMTPC), Ministry of Uraban affairs has brought out a vulnerability map in consultation with IMD which is very useful for disaster mamagers.

What are the different methods tried to modified the cyclone?

i. Seeding with silver iodide.

ii. Placing a substance on the ocean surface.

iii. By nuking them.

iv. By cooling the surface waters with deep ocean water.

v. By adding a water absorbing substance.

What are the future plans of IMD to strengthen the Cyclone warning setup?

- Strengthening of surface observational network with the state-of-the-art automatic weather stations (AWSs) models.
- A dense network of Satellite reporting rain gauges in the coastal region.
- Deployment of Wind Profilers and Cyclone Warning dissemination system.
- Increased S-Band Doppler Weather Radar network in the coastal region
- The up gradation of the computing facility in IMD that will place a computing platform capable of

running high-resolution global and regional models. It will be used for development of models for better prediction of tropical cyclone track and intensity.

- Augmentation of Cyclone Warning Dissemination System (CWDS) with state-of-the-art Digital CWDS
- Supply of satellite radio receivers to fishermen to receive cyclone warnings.
- IMD through Telecom Regulatory Authority of India (TRAI) is coordinating with different mobile service providers including MTNL & BSNL to work out the modalities of dissemination of disaster warning messages (Cyclone warnings) directly to the general public who live in vulnerable zones.

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FAQ, Joint Typhoon Warning Centre, USA

FAQ, National Hurricane Centre, USA