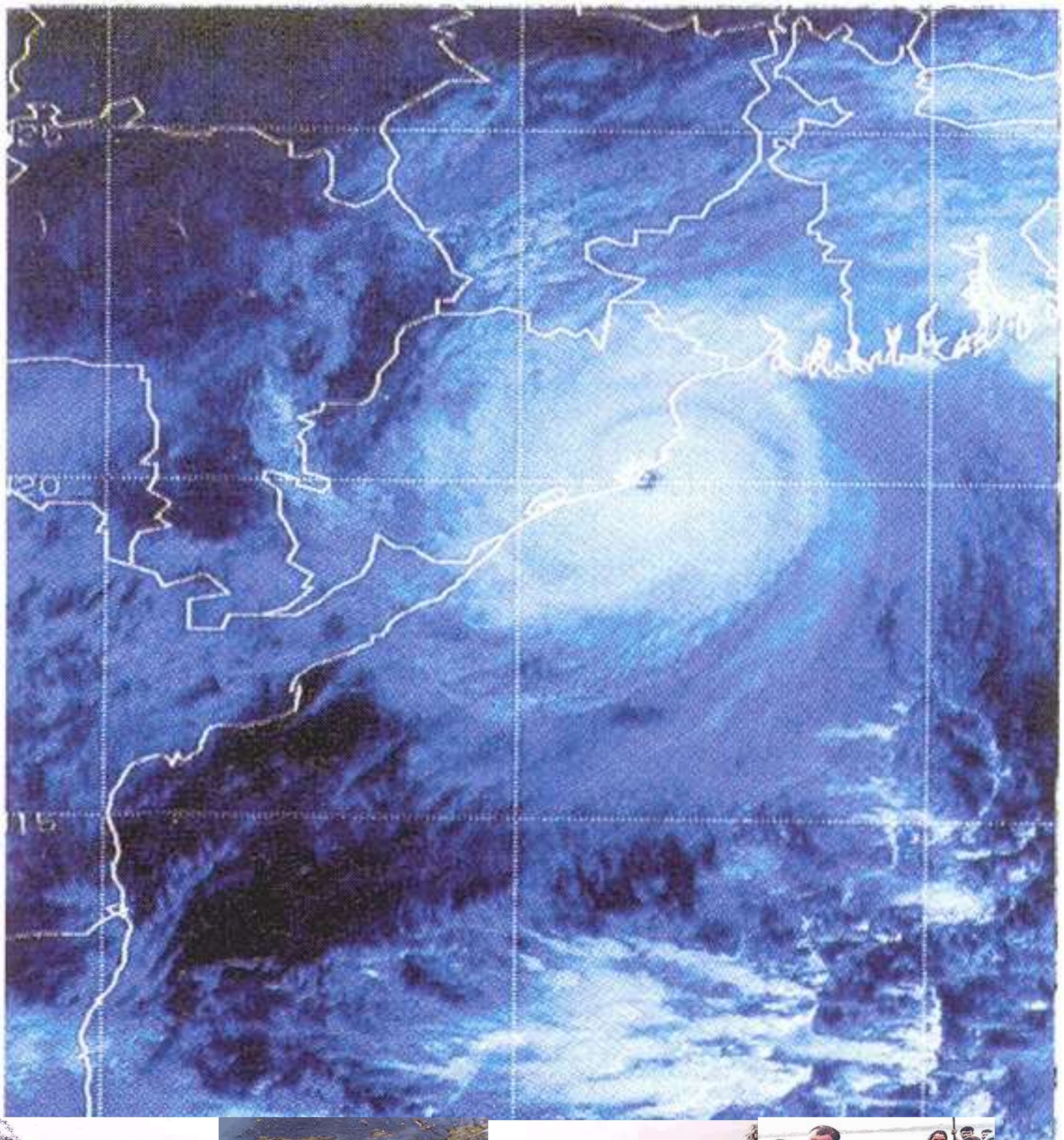

Damage Potential of Tropical Cyclone

Cyclonic disturbances are classified depending upon the wind speed around the circulation centre. Satellite cloud imageries are used alongwith other meteorological features to estimate the intensities and the wind speed associated with these intense systems. The satellite cloud configurations, expressed by 'T' numbers, have unique relationship with wind field of a cyclonic disturbance. The wind speed, condition of sea and wave height associated with 'T' numbers of various categories of cyclonic disturbances, are given in Table 1.

Table 1. : Categorisation of Cyclonic Disturbances

S. No.	Intensity	Strength of wind	Satellite 'T' No.	condition of Sea	Wave height (m)
1.	Depression (L)	31- 49 kmph (17-27 knots)	1.5	Moderate to Rough	1.25-2.5 2.5-4.0
2.	Deep Depression (DD)	50 – 61 kmph (28-33 knots)	2.0	Very Rough	4.0-6.0
3.	Cyclonic Storm (CS)	62 – 87 kmph (34-47 knots)	2.5-3.0	High	6.0-9.0
4.	Severe Cyclonic Storm (SCS)	88-117 kmph (48-63 knots)	3.5	Very High	9.0-14.0
5.	Very Severe Cyclonic Storm (VSCS)	118-166 kmph (64-89 knots)	4.0-4.5	Phenomenal	Over 14.0
6.	Extremely Severe Cyclonic Storm (ESCS)	167-221 kmph (9--119 knots)	5.0–6.0	Phenomenal	Over 14.0
7.	Super Cyclonic Storm (SuCS)	222 kmph and more (120 knots and more)	6.5 and more	Phenomenal	Over 14.0

The strong winds, heavy rains and large storm surges associated with tropical cyclones are the factors that eventually lead to loss of life and property.

The expected impacts in association with storm of different categories/intensities are summarized below.

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1. **Winds**

The damages produced by winds are extensive and cover areas occasionally greater than the areas of heavy rains and storm surges which are in general localized in nature. The impact of the passage of the cyclone eye, directly over a place is quite different from that of a cyclone that does not hit the place directly. The latter affects the location with relatively unidirectional winds i.e. winds blowing from only one side, and the leeside is somewhat protected. An eye passage brings with it rapid changes in wind direction, which imposes torques which can twist the vegetation or even structures. Parts of structures that were loosened or weakened by the winds from one direction are subsequently severely damaged or blown down when hit upon by the strong winds from the opposite direction. A partial eye passage can also do considerable damage, but it is less than a total eye passage.

As tropical cyclones have a circular shape, an eye passage over a location exposes it to the maximum possible duration of destructive winds. The higher wind is also associated with convectively active eye-wall region and has higher wind gusts than outside it. The gustiness effect is amplified over land where friction reduces sustainable wind but not the peak gust. This widens the gap between the peak and the lull of the gusts even more, creating strong negative pressure forces on lee-side of buildings especially damaging metal sheet and wooden structures. Strong wind also exposes roofs to strong lifting forces. The typical damage to buildings is due to failure of roofing systems. Loss of roof irrespective of the material used, leads to water damage of the walls. When the roofs get blown off, the exterior walls lose the support provided by the roofing systems and collapse even in lesser wind intensity.

Winds are stronger in the right semi-circle with reference to the direction of motion of the cyclonic storm in the Northern Hemisphere. Occasionally, very strong winds are also encountered to the left side of the storm with respect to its motion. The total damage is significantly greater than that from the relatively unidirectional winds of a near miss with comparable intensity.

Under the action of wind flow, structures experience aerodynamic forces that include the drag force acting in the direction of the mean wind, and the lift force acting perpendicular to that direction. The structural response induced by the wind drag is commonly referred to as the ‘along wind' response. It has been recognized that in the case of modern tall buildings which are more flexible, lower in damping, and lighter in weight than older structures, the natural frequency of vibration may be in the same range as the average frequency of occurrence of powerful gusts and therefore large resonant motions induced by the wind may occur. This must be taken into consideration in design of cyclone resistant buildings.

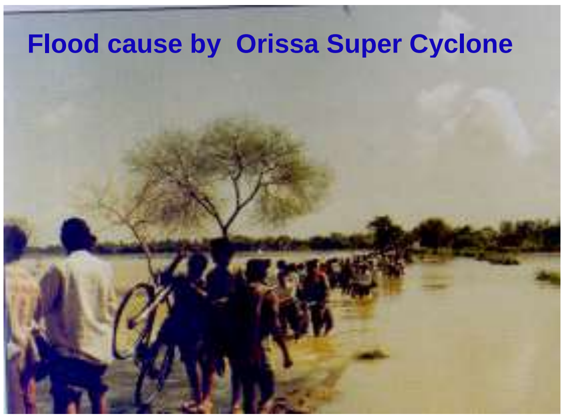

Damage caused by very severe cyclonic storm ‘Nargis’

Many of the overhead communication networks are susceptible to damage when the winds reach 85 Kts (158 Kmph), This is especially the case for secondary telephone lines.

Microwave towers are susceptible to misalignment when winds reach 85 Kts (158 Kmph). This affects local telephone, cellular service and long distance service. Microwave and radio towers are susceptible to destruction when winds reach 100 Kts (186 Kmph). At higher wind speed even larger antennas are also vulnerable and are blown off. Even large satellite communication dishes can be damaged in cyclones with sustained wind speeds of 135 Kts (251 Kmph). Coastal roads/locations are vulnerable to damage from inundation/waves run-up. The most detrimental hazards to roadways are uprooted trees, power poles and lines, and debris falling on roads and blocking them. This becomes a serious problem when winds reach 80 Kts (149 Kmph) or more.

2. Rainfall

Rains (sometimes even more than 30 cm per 24 hrs) associated with cyclones are another source of damage. Unabated rains give rise to unprecedented floods. Rainwater on the top of storm surge may add to the fury of the storm. Rain is an annoying problem for the people who become shelterless due to a cyclone. It creates problems in post cyclone relief operations.


Flood cause by Orissa Super Cyclone

On the infrastructure front, the most critical problem after passage of any tropical cyclone is the restoration of water distribution system. Strong winds along with heavy rains accompanied with floods/storm surge associated with the cyclone, devastate the critical parts of the power generation and distribution systems. Even the strongest port and airport facilities, fuel and water storage tanks, high voltage transmission tower, etc., are vulnerable to damage.

Rainfall is generally very heavy and spread over a large area thus leading to excessive amount of water, which leads to flooding. Soil erosion also occurs on a large scale. Heavy rains log the ground and cause softening of the ground due to soaking. This contributes to weakening of the embankments, the leaning over of utility poles or collapse of pole type structures.

3. Storm Surge


Storm surge caused by Very severe cyclonic storm 'Nargis'

Storm surge is the single major cause of devastation from tropical storms. Though, the deaths and destruction are caused directly by the winds in a tropical cyclone as mentioned above, these winds also lead to massive piling of sea water in the form of what is known as storm surge that lead to sudden inundation and flooding of coastal regions. The surge is generated due to interaction of air, sea and land. When the cyclone approaches near the coast, it provides the additional force in the form of very high horizontal atmospheric pressure gradient and which leads to strong surface winds. As a result, sea level rises and continues to rise, as the cyclone moves over shallower waters and reaches a maximum on the coast near the point of landfall. Storm surge is inversely proportional to the depth of sea water. The depth varies from about 500 m at about 20^0 N in the north central Bay to about 5 m along the West Bengal-north Orissa coast. Because of the vast shallow continental shelf, the storm surges get amplified significantly in these areas. The northward converging shape of the Bay of Bengal provides another reason for the enhanced storm surge in these areas.

There is another cause of sea level rise, viz., astronomical tide, which is well known. The rise due to high tide may be as high as 4.5 m above the mean sea level at some parts of Indian coast. The worst devastation is caused when the peak surge occurs at the time of high tide.

As the leading edge of the storm surge crashes against the coastline, the speed of the surge places great stress on the walls. The debris like uprooted trees, fences and parts of broken houses, act as battering rams and cause further damage. The sand and gravel carried by the moving currents at the bottom of the surge can cause sand papering action of the foundations. The huge volume of water can cause such pressure difference that the house "floats" and once the house is lifted from the foundations, water enters the structure that eventually collapses.

The expected damage associated with the cyclonic disturbances of different intensities along with action suggested is given in Table.2

Table 2. Storm Intensity, Expected Damage and Actions Suggested

Intensity	Damage expected	Action Suggested
Depression <31 kmph (<17 knots)	Minor damage to loose and unsecured structures	Fishermen advised not to venture into the open seas.
Deep Depression 50 – 61 kmph (28-33 knots)	Minor damage to loose and unsecured structures	Fishermen advised not to venture into the open seas.
Cyclonic Storm 62 – 87 kmph (34-47 knots)	Damage to thatched huts. Breaking of tree branches causing minor damage to power and communication lines	Total suspension of fishing operations
Severe Cyclonic Storm 88-117 kmph (48-63 knots)	Extensive damage to thatched roofs and huts. Minor damage to power and communication lines due to uprooting of large avenue trees. Flooding of escape routes.	Total suspension of fishing operations. Coastal hutment dwellers to be moved to safer places. People in affected areas to remain indoors.
Very Severe Cyclonic Storm 118-166 kmph (64-89 knots)	Extensive damage to kutcha houses. Partial disruption of power and communication line. Minor disruption of rail and road traffic. Potential threat from flying debris. Flooding of escape routes.	Total suspension of fishing operations. Mobilise evacuation from coastal areas. Judicious regulation of rail and road traffic. People in affected areas to remain indoors.
Extremely Severe Cyclonic Storm 167-221 kmph (90-119 knots)	Extensive damage to kutcha houses. Some damage to old buildings. Large-scale disruption of power and communication lines. Disruption of rail and road traffic due to extensive flooding.	Total suspension of fishing operations. Extensive evacuation from coastal areas. Diversion or suspension of rail and road traffic. People in affected areas to remain indoors.

	Potential threat from flying debris.	
Super Cyclone 222 kmph and more (120 knots and more)	Extensive structural damage to residential and industrial buildings. Total disruption of communication and power supply. Extensive damage to bridges causing large-scale disruption of rail and road traffic. Large-scale flooding and inundation of sea water. Air full of flying debris.	Total suspension of fishing operations. Large-scale evacuation of coastal population. Total suspension of rail and road traffic in vulnerable areas. People in affected areas to remain indoors.