STUDY NOTES · BASIC CONCEPT

What Are Tropical Cyclones, How Do They Form, and How Can Their Impacts Be Managed in India?

Disaster Management

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1. What Are Tropical Cyclones?

Tropical cyclones are intense low-pressure weather systems that develop over warm tropical or subtropical oceans. They are characterised by organised thunderstorms, strong winds and heavy rainfall. Depending on their intensity and track, they can cause coastal inundation, inland flooding, agricultural losses and extensive infrastructure damage.

India is vulnerable to tropical cyclones because of its long coastline, densely populated coastal settlements, dependence on agriculture and exposure to the Bay of Bengal and the Arabian Sea.

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2. How Do Tropical Cyclones Form?

Tropical cyclones generally develop when several atmospheric and oceanic conditions occur together.

1. **Warm ocean water:** Sea-surface temperatures of approximately 26.5°C or higher over sufficient depth can provide the heat and moisture needed for cyclone development.
2. **Moisture availability:** Warm seawater increases evaporation, supplying moisture to the atmosphere.
3. **Condensation and latent heat:** As moist air rises and cools, water vapour condenses. The release of latent heat supports further atmospheric uplift.
4. **Low-pressure development:** Rising air can contribute to the development and strengthening of a low-pressure system.
5. **Coriolis force:** Earth’s rotation helps organise the system into a rotating circulation. Tropical cyclones do not ordinarily develop directly over the equator because the Coriolis force is too weak there.
6. **Low vertical wind shear:** Strong changes in wind speed or direction with height can disrupt the organisation of a developing cyclone. Relatively low wind shear is generally favourable.

3. What Are the Major Features of a Tropical Cyclone?

Feature	Description
Eye	Relatively calm central region in a mature cyclone

Feature	Description
Eyewall	Ring of intense thunderstorms surrounding the eye, often containing the strongest winds
Spiral rainbands	Bands of thunderstorms extending outward from the central region
Low atmospheric pressure	Helps drive the circulation of air towards the storm centre
Strong winds	Can damage buildings, trees, power lines and communication networks
Heavy rainfall	Can cause flash floods, river flooding and waterlogging
Storm surge	Abnormal rise in coastal water levels associated with the storm’s winds and atmospheric pressure

The exact structure and intensity of a cyclone can change throughout its life cycle.

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4. Why Is the Bay of Bengal Vulnerable to Tropical Cyclones?

The Bay of Bengal experiences tropical cyclones due to warm ocean waters, favourable atmospheric conditions and seasonal weather patterns.

Major contributing factors include:

1. Warm sea-surface temperatures during favourable seasons.
2. High atmospheric moisture and conditions supporting deep convection.
3. Seasonal wind patterns and the movement of low-pressure systems.
4. The shape of the northern Bay of Bengal, which can influence storm-surge impacts along coastal areas.
5. Extensive low-lying coastal plains and river deltas that are vulnerable to inundation.

The Arabian Sea also experiences tropical cyclones. Their distribution, intensity and movement in both basins depend on changing oceanic and atmospheric conditions.

5. How Are Tropical Cyclones Classified in India?

The India Meteorological Department (IMD) classifies cyclonic systems according to their maximum sustained wind speeds.

System	Maximum sustained wind speed
Depression	31–49 km/h

System	Maximum sustained wind speed
Deep depression	50–61 km/h
Cyclonic storm	62–88 km/h
Severe cyclonic storm	89–117 km/h
Very severe cyclonic storm	118–166 km/h
Extremely severe cyclonic storm	167–221 km/h
Super cyclonic storm	222 km/h or more

Important distinction: Maximum sustained wind speed and wind gusts are not identical. Gusts are short-duration increases in wind speed and may exceed the sustained wind speed.

6. How Can Cyclones Benefit Drought-Prone Regions While Causing Destruction?

Cyclone rainfall can have contrasting effects, particularly in regions experiencing prolonged dry conditions.

Potential benefits

- **Rainfall replenishment:** Cyclone rainfall can increase reservoir storage and replenish surface-water resources.
- **Groundwater recharge:** In suitable geological and soil conditions, rainfall can contribute to groundwater recharge.
- **Improved soil moisture:** Rainfall can support subsequent agricultural activity if the amount and timing are favourable.

Adverse impacts

- **Flooding:** Intense rainfall can overwhelm drainage systems and cause flash floods, river flooding and prolonged waterlogging.
- **Crop destruction:** Strong winds, waterlogging and inundation can damage standing crops, orchards and stored agricultural produce.
- **Infrastructure damage:** Trees and power poles may be uprooted, roads damaged and electricity and communication services disrupted.
- **Coastal inundation:** Storm surges can flood low-lying settlements and agricultural land with seawater.
- **Public health risks:** Contaminated drinking water and damaged sanitation systems can increase health risks.

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The benefits of rainfall depend on its distribution, storage capacity, drainage, groundwater conditions and the extent of damage caused.

7. What Is a Storm Surge, and How Does It Affect Coastal Regions?

A storm surge is an abnormal rise in seawater level associated primarily with a storm’s winds and low atmospheric pressure. When it coincides with high tide, coastal flooding can become more severe.

Factors influencing storm-surge damage include:

1. Cyclone intensity and wind direction.
2. Coastal shape and the depth of nearshore waters.
3. Tidal conditions at the time of landfall.
4. Elevation of coastal settlements.
5. Natural barriers such as mangroves and coastal wetlands.
6. Population density and the quality of protective infrastructure.

Storm surges can cause damage even in areas that receive comparatively less rainfall. Coastal cyclone preparedness must therefore account for both wind-related and water-related hazards.

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8. How Do Tropical Cyclones Affect Agriculture and Rural Livelihoods?

Cyclones can affect agricultural communities through several pathways.

Impact	Consequence
Crop lodging and physical damage	Lower yields and reduced farm income
Waterlogging	Root damage and crop loss
Saline-water intrusion	Soil degradation and reduced agricultural productivity
Damage to irrigation infrastructure	Disruption of future agricultural operations
Livestock losses	Reduced household income and food security
Damage to storage and transport	Post-harvest losses and market disruption

Risk-reduction measures include crop insurance, resilient storage facilities, improved drainage, weather-based agricultural advisories, timely harvesting where feasible and rapid assessment of crop losses.

9. What Is the Role of the India Meteorological Department in Cyclone Management?

The **India Meteorological Department (IMD)** is India’s principal agency for weather forecasting and cyclone warnings.

Its functions include:

1. Monitoring atmospheric and oceanic conditions.
2. Tracking the location, movement and intensity of cyclonic systems.
3. Issuing forecasts and warnings to government agencies and the public.
4. Providing information on wind speeds, heavy rainfall, storm surge and likely landfall areas.
5. Supporting disaster-management authorities in preparing evacuation and response plans.

Forecasting has improved through satellite observations, weather radar, numerical weather prediction and better communication systems. However, translating forecasts into timely action remains essential.

10. How Does India Manage Cyclone Disasters?

India’s disaster-management framework involves coordination between national, state and local institutions.

National Disaster Management Authority (NDMA): Provides national-level policy guidance and frameworks for disaster preparedness and risk reduction.

National Disaster Response Force (NDRF): Conducts specialised response operations, including rescue and relief in affected areas.

State Disaster Management Authorities (SDMAs): Coordinate state-level preparedness and response.

District administrations: Organise local evacuation, shelters, relief distribution and restoration of essential services.

Local bodies and community organisations: Help disseminate warnings, identify vulnerable households and support relief operations.

IMD: Provides meteorological information that supports these decisions.

Effective cyclone management requires clear communication, defined responsibilities and coordination across institutions.

11. What Are the Four Stages of Cyclone Disaster Management?

Cyclone management includes four connected stages.

1. Mitigation: Reducing long-term risk through resilient buildings, improved drainage, coastal ecosystem conservation and safer land-use planning.

2. Preparedness: Developing evacuation plans, maintaining cyclone shelters, conducting drills and ensuring that essential supplies are available.

3. Response: Evacuating vulnerable populations, conducting rescue operations, providing food and medical assistance, and restoring essential communication.

4. Recovery: Repairing infrastructure, restoring livelihoods, rebuilding homes and improving resilience based on lessons from the disaster.

A strong disaster-management system integrates all four stages rather than relying only on post-disaster relief.

12. How Can Early Warning Systems Reduce Cyclone Damage?

Early warnings save lives when they reach people in time and lead to practical action.

Important measures include:

- Communicating warnings in local languages through multiple channels.
- Identifying evacuation routes and safe shelters in advance.
- Prioritising older persons, children, persons with disabilities and other vulnerable groups.
- Ensuring that fishermen and coastal communities receive timely warnings.
- Maintaining emergency power, drinking water, food and medical supplies.
- Preventing people from entering flooded roads, beaches and damaged buildings during dangerous conditions.

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Warnings must explain not only the expected hazard but also the actions people should take.

13. How Can Climate Change Influence Cyclone Risks?

Climate change can influence tropical cyclone hazards through changes in ocean temperatures, atmospheric moisture and sea levels. The relationship between climate change and the frequency of all tropical cyclones is complex and varies by basin.

Warmer oceans: Higher ocean heat content can support more intense rainfall and may favour stronger storms under suitable conditions.

Sea-level rise: A higher baseline sea level can increase the extent of coastal flooding caused by storm surges.

Extreme rainfall: A warmer atmosphere can hold more moisture, potentially increasing rainfall intensity in suitable storm conditions.

Compound risks: Cyclone winds, rainfall, storm surge and high tides can combine to produce greater damage than any single hazard alone.

Climate adaptation should therefore include coastal protection, resilient infrastructure, ecosystem conservation and improved disaster preparedness.

14. How Can India Improve Cyclone Preparedness and Disaster Risk Reduction?

Strengthen forecasting: Improve observation networks, radar coverage and the communication of localised warnings.

Build resilient infrastructure: Protect electricity networks, roads, communication systems and essential public services against strong winds and flooding.

Improve coastal planning: Avoid inappropriate construction in highly vulnerable coastal areas and preserve natural protective ecosystems.

Support farmers: Provide accessible crop insurance, agricultural advisories, drainage improvements and timely compensation after verified losses.

Enhance community participation: Conduct evacuation drills and involve local communities in risk assessment and emergency planning.

Adopt an integrated approach: Combine cyclone preparedness with drought management, water storage, watershed planning and climate adaptation.

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15. Conclusion

Tropical cyclones demonstrate the complex relationship between natural hazards and human vulnerability. They may provide rainfall to drought-prone regions, but excessive precipitation, storm surges and strong winds can destroy crops, damage infrastructure and threaten lives. India’s approach must combine reliable forecasting, timely evacuation, resilient infrastructure, ecosystem conservation and long-term recovery planning. The objective should be not merely to respond to cyclones, but to reduce the risks and vulnerabilities that turn extreme weather into disasters.