Climate Action in Cities
CoCHAP

# Coastal Cities Resilience and Extreme Heat Action Project

## Coastal Hazards in Cities Fact Sheets #2

## Tropical Storms

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USAID FROM THE AMERICAN PEOPLE
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# Tropical Storm in Coastal Cities

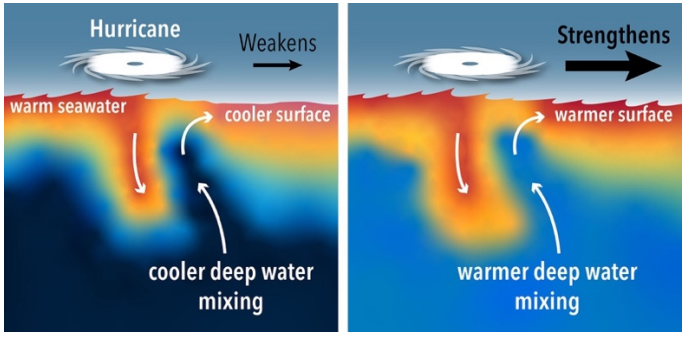


## What is a Tropical Storm?

A tropical storm is a weather system characterized by strong winds and heavy rainfall that develops over warm ocean waters in tropical and subtropical regions. Wind speeds in tropical storms (also called hurricanes or typhoons, in different parts of the globe) can range from 63 to 118 km (39 to 73 miles) per hour.[i] [ii] The IPCC Special Report on Ocean and Cryosphere in a Changing Climate states that coastal hazards will be exacerbated by an increase in the average intensity, magnitude of storm surge and precipitation rates of tropical cyclones (medium confidence).[iii]

According to the World Meteorological Organization (WMO), in the last half-century, 1,942 disasters were related to tropical cyclones, resulting in the loss of 779,324 lives and causing economic losses close to $1,5 billion. On average, this translates to 43 fatalities and $78 million in damages occurring daily.[iv]

Figure 1: Figure showing hurricanes drawing its energy from warm surface ocean waters[v]



## Causes of Tropical Storm:

- Warm Ocean Water: When the sea surface temperature reaches 26 degrees Celsius or more, it provides the necessary heat and moisture to fuel the storm. Warm ocean water serves as the energy source for the storm.[vi]
- Atmospheric Instability: Tropical storms thrive in regions where the atmosphere is unstable. This means that warm, moist air at the surface rises and creates a low-pressure system. As this air rises, it cools and condenses, releasing heat and further intensifying the storm. This difference in temperature creates a storm.[vii]
- Low-Pressure System: A tropical storm begins with the formation of a low-pressure area at the surface. The convergence of warm, moist air into this low-pressure center sets the stage for further development.[viii]
- Coriolis Effect: The Coriolis effect, caused by the Earth's rotation, causes a spinning motion rotating counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, which can contribute to the occurrence of tropical storms.[ix]
- Distance from the Equator: Tropical storms typically form over regions more than 5 degrees of latitude of the equator.[x]

## How does Climate Change affect Tropical Storms?

- Warmer Ocean Temperatures: According to IPCC Sixth AR, by 2100, the ocean is very likely to warm by 2 to 4 times as much for low emissions (RCP2.6) and 5 to 7 times as much for the high emissions scenario (RCP8.5) compared with the observed changes since 1970. Climate change leads to higher sea surface temperatures, providing the energy needed to fuel tropical storms. Warmer oceans can increase evaporation and moisture in the atmosphere, enhancing storm development and intensification.
- Increased Water Vapor in the Atmosphere: The IPCC Sixth AR Sixth states that the total atmospheric water vapour is increasing by 1 to 2% per decade.xi As the GHG emissions increase, temperature increases, increasing water vapour in the atmosphere. This additional moisture can fuel tropical storms, leading to heavier rainfall and potentially more intense storms.
- Warming in the Upper Atmosphere: As per NASA, hurricanes are fuelled by heat in the ocean's top layers and require sea surface temperatures (SSTs) greater than 79 degrees Fahrenheit (26 degrees Celsius) to form and thrive. While the lower atmosphere warms due to climate change, the upper

atmosphere cools. The temperature difference can create conditions that are more favourable for storm intensification.

## How does Tropical storm affect city systems?

**Physical Impacts**

- Power Grid: Strong winds and falling trees can damage power lines and substations, causing widespread power outages in the city. These outages can last days or weeks, affecting homes, businesses, hospitals, and other essential services.xii
- Water Supply: Flooding due to the storm can lead to contamination of water treatment plants, which can affect the city's water supply. This can impact access to clean drinking water and create sanitation issues.xiii
- Public Transit: Mass transit systems, including buses and trains, can be severely affected by flooding and power outages caused by the storm. This disrupts the daily commute for many residents and hampers the ability of cities to evacuate people from vulnerable areas.xiv
- Communication Infrastructure: Tropical storms can disrupt communication networks, including cellular and landline services. This hinders emergency communication and coordination efforts during emergencies.xv
- Damage to Coastal Vegetation: Coastal vegetation, such as mangroves and salt marshes, play a crucial role in buffering against storm surges and erosion. However, coastal development and habitat destruction by human activities have led to the loss of these protective ecosystems. As a result, coastal areas are more susceptible to the impacts of tropical storms, including saltwater intrusion into freshwater sources.

In 2020, Tropical Storm Isaias in the north eastern United States storm brought strong winds and heavy rainfall, causing extensive damage to the power grid, with thousands of utility poles toppled and numerous power lines downed. In certain regions, power restoration went on for several days, resulting in prolonged electricity outages, impacting businesses, and causing disruptions in their daily lives.[xvi]

In 2007, Bangladesh experienced a devastating tropical cyclone called Sidr on November 15th. This potent storm generated waves reaching up to 30 feet, killing over 10,000 lives.[xvii] Damages to agricultural engineering infrastructures such as rural roads, embankments, water sanitation, shelters and food security were reported.

**Socio-Political Impacts**

- Loss of Life and Injury: Tropical storms causing floods, high winds, and debris can result in fatalities and injuries among residents, causing physical injuries and trauma.[xviii]
- Displacement and Relocation: Tropical storms can force communities to relocate to safer areas, disrupting daily life and adding mental and emotional stress.[xix]
- Community Disruption and Social Inequity: The displacement can fragment communities and cause social inequity as they are forced to start their lives elsewhere.
- Increased Vulnerability: Vulnerable populations, such as the elderly, disabled, and low-income individuals and children, are often disproportionately affected by tropical storms due to limited resources and mobility challenges.[xx]

**Environmental Impacts**

- Habitat Destruction: The strong winds of tropical storms can uproot trees, break branches, and damage vegetation, destroying habitats for both terrestrial and aquatic species.[xxi]
- Landslide and Erosion: Tropical storms can lead to coastal erosion and landslides, altering the shape of coastlines.[xxii]
- Water Pollution: Heavy rainfall and winds can introduce pollutants, sediments, and debris into rivers, lakes, and coastal waters, causing harm to marine species.
- Coral Reefs and Mangroves: The increased wave action associated with tropical storms can cause physical damage to coral reefs and mangrove ecosystems.[xxiii]
- Loss of Biodiversity: Alteration in the habitat of plant and animal species can result in the loss of keystone species.[xxiv]
- Wetlands and Marshes: Storm surges and heavy rainfall can alter wetlands and marshes' water levels and salinity, affecting the flora and fauna that depend on these environments.
- Nesting Sites: Nesting sites for sea turtles and shorebirds may be impacted by tropical storms, causing nest destruction and affecting their breeding.[xxv]

Hurricane Harvey in Houston, Texas, in 2017 caused a devastating impact with high-intensity rainfall. The storm caused widespread flooding in the Houston metro area and carried pollutants in the wastewater treatment plants and industrial facilities of the Gulf of Mexico.[xxvi] Over 700,000 gallons of pollutants are released into water or on land, causing adverse effects on aquatic wildlife and fisheries.[xxvii]

## Adaptation Strategies for Tropical Storm

**Community Level**

- Identify and create safe shelters within the community that can withstand strong winds and flooding during emergencies caused by tropical storms.[xxviii]
- Encourage elevated construction techniques to raise homes and critical infrastructure above flood levels.[xxix]
- Encourage households to maintain emergency food and water supplies that sustain them during and after a storm.[xxx]
- Promote livelihood diversification to reduce the community's economic dependence on industries vulnerable to storm damage, such as tourism or fishing[xxxi]
- Develop post-storm recovery plans to facilitate rapid response and aid distribution.
- Application of Nature-Based-Solutions like Mangrove restoration, beach nourishment, wetland restoration to manage tropical storms.[xxxii]
- Implement green infrastructure practices such as rain gardens, permeable pavements, and bioswales to manage stormwater in urban areas.[xxxiii]
- Engage community members to map areas with high risk of tropical storms and encourage vulnerable communities to plan relocation.
- Monitor and research tropical storm patterns, frequency, and the impacts on lives and property.
- Encourage communities to engage in planning and implementing conservation efforts and raising awareness about the risks of tropical storms.
- Educate and create awareness among local communities about tropical storm risks, their causes, and the importance of adaptation through community workshops, training, information campaigns, and programs in schools and communities.
- Capacity building of local communities by providing them with training and education in the risks and management of tropical storms.[xxxiv]
- Collaboration and networking through combined workshops and engagements by bringing in residents, technical experts, environmental experts, businesses and local leaders, local and municipal government bodies together for consultation on tropical storms
- Establish early warning systems to monitor and create communication systems about tropical storms to alert residents to potential threats[xxxv]

**Municipal/Government Level**

- Beach and shoreface nourishment in which the sand is spread over the beach where erosion is occurring to compensate shore erosion and restore the recreational value of the beach.[xxxvi]
- Construction of sea walls and sea dikes, dams, channels, breakwaters, jetties, and artificial reefs along the coastline to protect land from the impact of waves and storm surges[xxxvii]
- Update or develop infrastructure and building codes that require erosion-resilient designs and elevated foundations for structures in coastal zones[xxxviii]
- Dune construction and strengthening by planting grass, covering the face of the dune with plant debris, construction of fences along the seaward face of the dune to reduce wind speed on the surface and applying combination of hard man-made structures topped with sand, dunes and vegetation.[xxxix]
- Adaptation of storm management plans through grey protection solutions (groynes, break walls) and promotion of green measures, including mangrove restoration and wetland management[xl]
- Retreat from high-risk areas by removing infrastructures too close to the beach or rivers without proper authorization by providing compensation and demolition costs[xli]
- Cliff strengthening and stabilisation, changing the slope angle, and/or reducing cliff heights by removing unstable blocks, eliminating surface runoff and infiltration on the slope, securing unstable rocks to increase cohesion and stability, preventing slippage, etc.
- Building storm surge gates and flood barriers to protect highly vulnerable urban areas and infrastructure where storm surges and sea flooding could have significant impacts[xlii]
- Strengthening and proper planning of road and transportation, water supply and sewage systems in case of emergencies in landslide-prone areas
- Fund research and innovation initiatives aimed at developing new tropical storm adaptation technologies, materials, and strategies[xliii]
- Participate in international agreements and conventions that address tropical storms, promoting cooperation and shared knowledge.[xliv]

## Case Examples

**Case Example 1**

The city of Bali in Indonesia has been actively promoting green building practices through initiatives such as the Bali Green Building Initiative (BGBI) as a part of

Nature Based Solutions to combat natural disasters like tropical storms. Several Indonesian cities have seen an increase in green building certifications, such as Green Building Council Indonesia's (GBCI) certification programs. These certifications encourage sustainable construction and renovation practices.[xlv]

**Case Example 2**

Over the last four decades, there has been a remarkable reduction in cyclone-related fatalities in various cities in Bangladesh, decreasing by more than 100 times. In 1970, cyclones claimed the lives of 500,000 individuals, whereas in 2007, the number dropped significantly to 4,234.17. Khulna, a major city in southwestern Bangladesh, has implemented adequate measures to combat tropical storms and cyclones. The city is located along the coastal region and is vulnerable to storm surges. Success stories in Khulna include the construction of cyclone shelters, early warning systems, and the planting mangrove forests to act as natural barriers against storm surges. Chittagong, the second-largest city in Bangladesh and a major coastal port city has improved drainage systems, built cyclone shelters, and developed early warning systems to protect its residents from storm-related hazards.[xlvi]

**Case Example 3**

Colombo, the capital city of Sri Lanka, is vulnerable to flooding and storm surges. The city has undertaken the Colombo Urban Regeneration Project (CURP) which is a comprehensive initiative aimed at enhancing the resilience of to various environmental challenges, including flooding and storm surges. Led by government agencies and local authorities, CURP encompasses a range of strategies and interventions designed to mitigate the impacts of natural disasters and improve the overall livability and sustainability of the city. One of the primary objectives of CURP is to address the vulnerability of Colombo to flooding, particularly during the monsoon seasons, and to strengthen the city's capacity to manage stormwater effectively. The project includes the implementation of flood management measures such as the construction of drainage infrastructure, canals, and flood barriers. These interventions are designed to improve the city's ability to withstand heavy rainfall and reduce the risk of inundation in low-lying areas. In addition to flood management, CURP also focuses on enhancing green spaces and natural habitats within the city to provide additional resilience against natural disasters. This includes initiatives such as the protection and restoration of wetlands, mangrove forests, and other natural buffers that can absorb excess water, mitigate erosion, and provide habitat for biodiversity.[xlvii]

**Case Example 4**

Darwin, located in Australia's Northern Territory, is prone to cyclones and tropical storms. The city has implemented the Darwin Stormwater Harvesting and Reuse

Scheme, which involves capturing and storing rainwater for irrigation and groundwater recharge during dry periods. Additionally, the city has invested in cyclone-resistant building designs and early warning systems to protect residents and infrastructure from storm-related hazard. [xlviii]

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