Chapter 15 Case Studies and Study Guide: Hurricanes

Key Concepts

- Unlike cold winter storms, hurricanes are strictly tropical storms with a warm core in the center. They are tropical cyclones.
- Hurricanes need warm tropical marine moisture to grow and sustain themselves
- Hurricanes dissipate over land and over colder oceans.
- Hurricanes therefore do not cross entire continents. However, they can be fed by already existing extratropical storms and move far into continents.
- Unlike tornadoes, hurricane can be up to 1500 km across though the center (eye of the hurricane is only tens of kilometers across)
- Hurricane season in central and north America is from June through October where hurricanes are typically strongest toward the end of the season.
- Hurricanes do not cross the equator as a result of the Coriolis effect
- Hurricanes have outer rainbands, and eye in the center and an eyewall where the strongest winds blow.
- While fair weather is found in the eye of a hurricane, the strongest winds are found in the eyewall around it.
- Hurricanes are destructive because they are associated with intense rainfall, high winds speeds, large waves in the open ocean and a high storm surge approaching the coast.
- Hurricane surges build up as a result of high winds that push waves together, and the low central pressure pulls the sea surface upward. Surges are enhanced when the hurricane makes landfall during high tide.
- The Saffir-Simpson scale rates hurricane strength in 5 categories.
- Locally, the winds speed is a combination of the travel speed of the hurricane and wind speeds in the rainbands and eye wall. The strongest winds are found where both show in the same direction. Due to the Coriolis effect, this is on the right side of the eye.
- Hurricanes need tropical ocean moisture and weak winds aloft to be able to form.
- The developing stages of a hurricane are: tropical disturbance, tropical depression, tropical storm, hurricane.
- Hurricanes have different names in different oceans. They are called typhoon in the western Pacific, and cyclone in the Indian ocean.
- Of all oceans, the western Pacific has the highest number hurricanes, and also the strongest. More hurricanes occur in the eastern Pacific than in the Atlantic.
- There are no hurricanes in the southeastern Pacific and the southeastern Atlantic. Hurricanes are also very rare in the southwestern Atlantic.
- In the north Atlantic, hurricanes are typically Cape Verde-type or Caribbean-type, depending one where they form.

- The Coriolis effect gives hurricane tracks a curvature to the right in the northern hemisphere, leading to a clock-wise loop.
- During El Niño years, less hurricanes than usual occur in the Atlantic but more than usual in the east Pacific. During La Niña years, the opposite is the case.
- Hurricanes forming in the east Pacific currently do not make landfall in southern California because they dissipate quickly when encountering the cold California Current approaching from the north.
- Barrier islands take on the brunt of ocean waves and protect the beaches behind them. Barrier islands and low-lying beaches are particularly vulnerable to erosion by hurricanes.
- Artificial structures for local protection of beaches and cliffs may cause enhanced erosion elsewhere, and even locally. They are often only temporary structures that need replacing.

Key Terms

- Hurricanes
- Tropical cyclones
- Hurricane season
- Storm dissipation
- Storm surge
- Eye of the hurricane
- Outer rainbands
- eyewall
- Saffir-Simpson scale
- Tropical disturbance
- Tropical depression
- Tropical storm
- Typhoon
- Cape Verde-type
- Caribbean-type
- El Niño/La Niña
- California Current
- Barrier islands
- Coastal erosion
- Coastal protection

Questions for Review

1. Under which atmospheric conditions do hurricanes form? What about ocean conditions?

2. How large can hurricanes become?

3. Describe why hurricanes are so destructive.

4. Which factors contribute to a large hurricane storm surge?

5. What are the three basic features of a hurricane? Where do we find the strongest winds?

6. Describe the developing stages of a hurricane? Does every tropical storm become a hurricane?

7. Which scale describes the strength of a hurricane? How does it compare to the tornado scale?

8. Where do Atlantic hurricanes typically form?

9. Describe the paths of hurricanes on the north Atlantic.

10. What are hurricanes called in other oceans?

11. Which of the major oceans has the highest occurrence of hurricanes?

12. Are there oceans with no hurricanes? What prevents hurricanes from forming there?

13. Why do hurricanes not cross the equator?

14. Describe the relationship between frequency of hurricanes in the Atlantic and El Niño. Do the same for east Pacific hurricanes. Explain why this is different from normal years.

15. Why do east Pacific hurricanes traveling north quickly dissipate before they approach southern California?

16. What is a barrier island?

17. How can coasts and beaches be protected from incoming ocean waves and storm surges?

Case Studies

Case Study 1: 2005 Hurricane Katrina

Hurricane Katrina was only the 3rd strongest of a very busy Atlantic hurricane season. But it was the most destructive, with over 1800 fatalities and large destruction from the storm surge in New Orleans but also elsewhere. The Caribbean-type hurricane formed near the Bahamas on 23 Aug. It crossed the southern tip of Florida two days later and quickly strengthened to a category 5 hurricane within 9 hours after it entered the Gulf of Mexico on 26 Aug. It turned north toward Louisiana, slowed and weakened to category 3 before making landfall on 29 Aug, causing widespread catastrophic flooding. In New Orleans levees failed at 50 locations, including 3 key locations (Industrial Canal, 17th Street Canal, London Ave Canal), leading to flooding in 80% of the city. Located about 10 m below sea level, New Orleans has to be protected by levees and pumps from the higher ocean (Lake Pontchartrain to the north) as well as the Mississippi River to the south.

Subsequent investigations determined that the levees themselves were tall enough to protect against the storm surge. But the weak ground beneath shifted and caused a movement and subsequent breach of the levees. The Army Corps of Engineers that is responsible to build and maintain the levees eventually found that the design of the levees had some weaknesses. Evacuation was voluntary or mandatory for 1.2 million residents but many people stayed in New Orleans. First response was overwhelmed, shelters were overrun and looting was reported. FEMA provided housing assistance to 700,000 applicants. Katrina also damaged oil infrastructure. At the time, Katrina was the most costly natural disaster worldwide in terms of insured losses.

More than 1800 people lost their lives, and many had to relocate only to never come back. Relocation rates were particularly high among African Americans. The lower 9th Ward where homeownership among African-Americans was relatively high, was particularly hard hit. According to census data, less that 1/5 of people living in the 9th Ward 5 years before the hurricane still lived there (or returned) 5 years after the hurricane. While subsequent cleanup concentrated on the heart of New Orleans, it nevertheless took several years before street cars operated again.

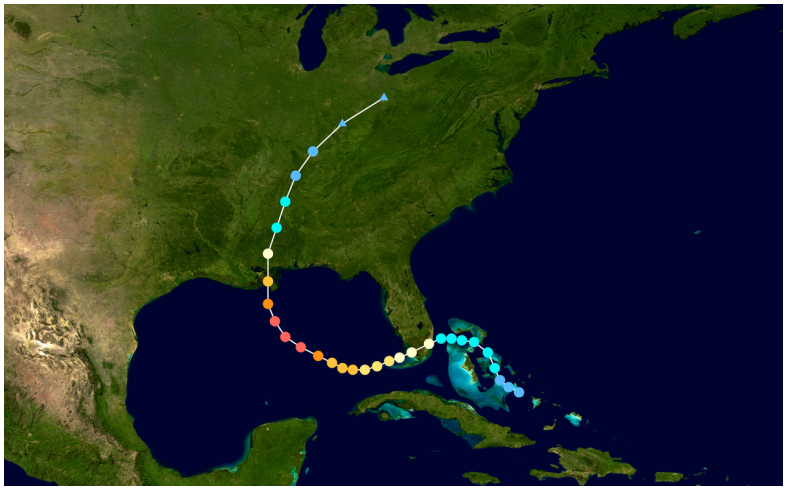

Figure 15.C1 Track of 2005 Hurricane Katrina. Katrina was a Caribbean-type hurricane. It strengthened quickly to category 5 (red) in the Gulf of Mexico but weakened to category 3 (orange) before landfall in Louisiana on 29 Aug. Triangles mark the storms history as an extratropical cyclone. (source: Wikipedia/NASA)

City of New Orleans Ground Elevations
From Canal St. at the Mississippi River to the Lakefront at U.N.O.

Figure 15.C2 Vertical cross-section of New Orleans, showing maximum levee height of 7 m (23 ft). Vertical scale exaggerated. New Orleans lies below sea level and has to be protected by levees and pumps against the ocean (right; Lake Ponchartrain) but also against the Mississippi River (left). (source: Wikipedia/NASA)

Case Study 2: 2012 Superstorm Sandy

Hurricane Sandy claimed 233 lives and was nearly as costly as Hurricane Katrina. The hurricane formed very late in the season on 22 Oct in the southern Caribbean Sea. Sandy hit Cuba three days later as a category 3 hurricane. It claimed 11 lives in Cuba but 54 in neighboring Haiti where 200,000 were made homeless by heavy rain.

Sandy then moved north and weakened. But it strengthened again after encountering a Nor'Easter on 27 Oct. The combined Superstorm Sandy turned into an extratropical storm before making landfall in New Jersey on 29 Oct. It affected 24 states, killing 157 in the U.S..

In the U.S., government weather forecasters predicted that the 'Frankenstorm' would have a 90% chance to impact the East Coast. Model forecasts predicted that 10 million customers would lose electric power. Airlines canceled 13,000 flights on 29 Oct, and rail travel was partially suspended on 29 Oct, from Washington, DC to New York City. Parts of New Jersey (incl. all barrier islands) and new York were evacuated and the subway was suspended. New York's Battery Island was hit full force as the storm surge arrived at the peak of high tide. New Jersey's barrier islands suffered extensive coastal erosion. On 31 Oct, over 6 million customers were still without power in 15 states. New York and New Jersey were particularly badly affected, and NY Stock Exchange and NASDAQ were closed for 2 days.

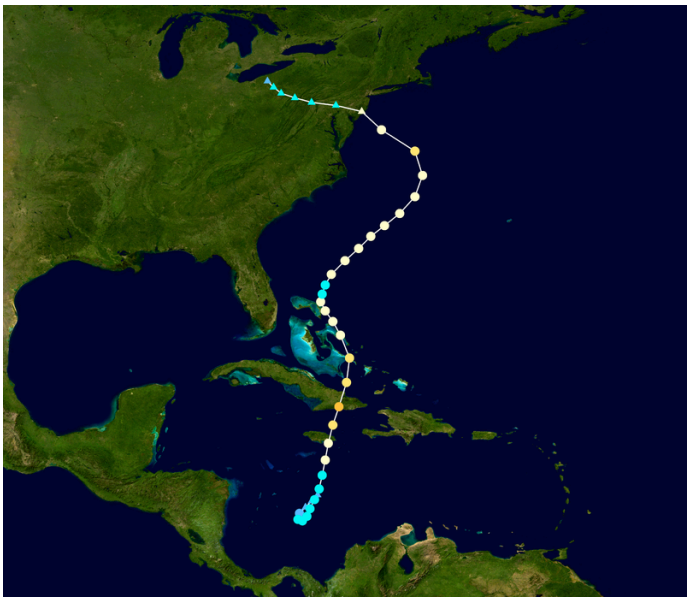

Figure 15.C3 Track of 2012 Superstorm Sandy. Sandy formed very late in the season on 22 Oct and started as a Caribbean-type hurricane. Sandy hit Cuba three days later as a category 3 hurricane (orange) and then weakened. Farther north, it encountered a Nor'Easter, strengthened and turned into an extratropical storm before making landfall new New Jersey on 29 Oct. (source: Wikipedia/NASA)

Figure 15.C4 Track of 2012 Aerial views during an Army search and rescue mission show damage from Superstorm Sandy to the New Jersey coast, 30 Oct 2012. (source: Wikipedia/U.S. Air Force)

Case Study 3: 2017 Hurricane Maria

Hurricane Maria was the second-deadliest hurricane to U.S. citizens, after the unnamed 1900 hurricane that flooded Galveston, TX. The official death toll from Maria did not match the actual death toll for over a year, but initial numbers of 65 were later corrected to upward of 3000. Initial estimated of $8 billion in damages now stand at over $90 billion, on par with Hurricanes Katrina and Sandy. Maria effectively destroyed Puerto Rico's already ailing power grid. Maria's storm surge, reaching nearly 5 m in places flooded many coastal areas. Across the island's interior, numerous landslides cut villages off from the outside world.

Maria became a tropical storm on 16 Sep and intensified explosively to category 5 within only 2 days. At that time, it made landfall on the island of Dominica, claiming 65 lives, damaging 85% of houses of which more than 25% were destroyed. 50,000 of the island's 73,000 residents were displaced. Hurricane Maria continued on to strike Puerto Rico as a category-4 hurricane on 20 Sep.

In preparation of the onslaught, Puerto Rico opened 450 shelters on 18 Sep, but only 2000 people had sought shelter by 19 Sep. Many fled to island to the U.S. mainland. Puerto's drinking water system and electrical grid was already substandard, with 70% of the islanders having water that did not meet the standards of the 1974 Safe Drinking Water Act. Poor maintenance and outdated control system also taxed the power grid. Before the arrival of Maria, 80,000 customers were still without power after Hurricane Irma had hit the island 2 weeks earlier. Most of FEMA's supplies stored at warehouses in Puerto Rico were shipped to the U.S. Virgin islands to help Irma victims. So Puerto Rico was ill-prepared for a second devastating hurricane in two weeks. Maria essentially destroyed Puerto Rico's power grid, leaving 3.4 million people without power. This included almost all of cell phone coverage (95%), above-ground phone and internet

(85%). Only 12 radio stations remained on the air during the storm. Repair to the electrical grid was slow and riddled with blackouts. So were 700,000 customers without power in April 2018, more than 6 months after the hurricane hit. Seven months after the hurricane, tens of thousands of customers had yet to be reconnected to the grid.

Puerto Rico is an unincorporated territorial possession of the U.S., and Puerto Ricans have been U.S. citizens since 1917. The Merchant Marine Act of 1920 (also Jones Act, not to be confused with the Jones Act of Puerto Rico that gives Puerto Ricans U.S. citizenship) requires that all goods transported by water between U.S. ports be carried on U.S.-flag ships, constructed in the U.S., owned by U.S. citizens, and crewed by U.S. citizens and permanent residents. This means that international disaster relief was not allowed to reach Puerto Rico. Meanwhile, the U.S. government slowly and inadequately reacted, including a delay in waiving the Jones Act. On 3 Oct, president Trump toured the island, effectively belittling its death toll and damage as compared to a 'real catastrophe like Katrina'.

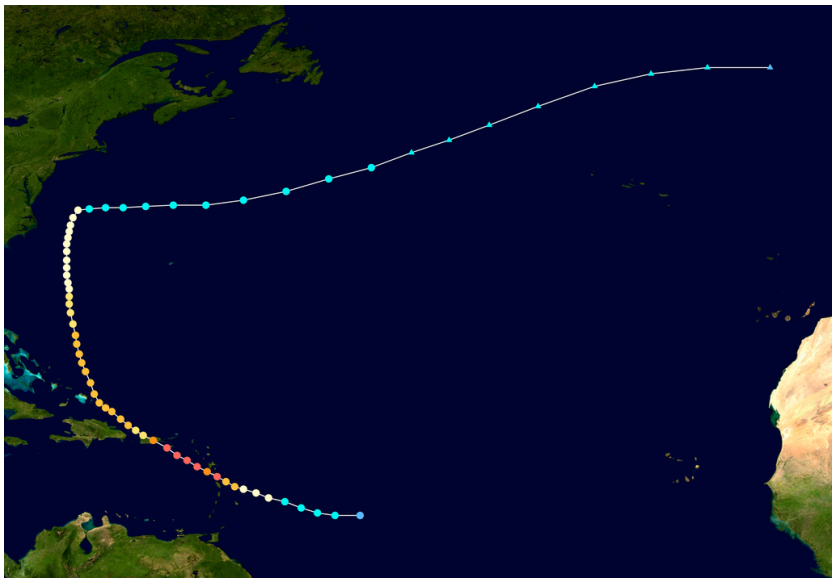

Figure 15.C5 Track of 2017 Hurricane Maria. Maria became a tropical storm on 16 Sep (light blue). Favorable conditions fueled an explosive growth to a category 5 hurricane on 18 Sep (red) thereby devastating the island of Dominica. Two days later, Maria struck Puerto Rico as a category-4 hurricane on 20 Sep (dark orange). Maria then slowly degraded and weakened to a tropical storm on 28 Sep, becoming an extratropical storm on 30 Sep and dissipating on 2 Oct. (source: Wikipedia/NASA)

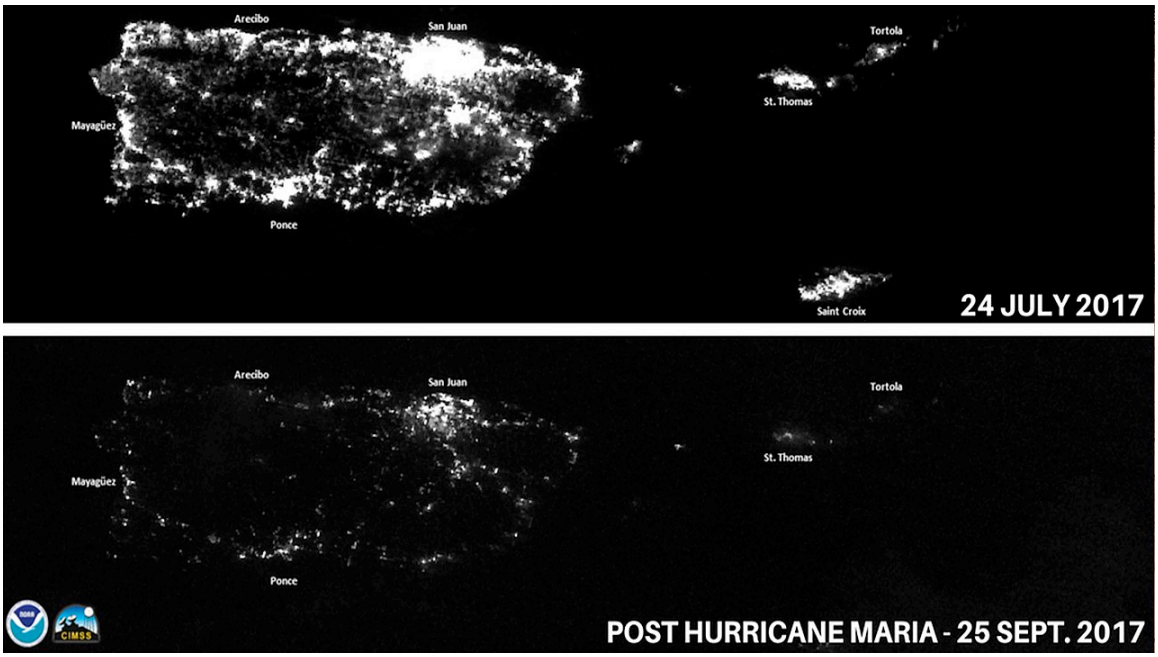

Figure 15.C6 Comparison of lights at night in Puerto Rico before (top) and after (bottom) Hurricane Maria. Very few, and only some areas in the capital San Juan were still with electrical power. (source: Wikipedia/NOAA)