Coastal Hazards: Severe Storms and Rising Seas

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Coastal change occurs on two different time scales. Short-term change is mostly caused by severe storm events, whereas long-term change is commonly attributed to more persistent increases in relative sea level. Together, the effects of storm waves and relative rise in sea level are largely responsible for coastal change.

Severe Storms

Major storms are common events in comparison to major earthquakes, tsunamis, and catastrophic volcanic eruptions. Each summer, at least 10-12 named hurricanes and tropical storms become the focus of nation-al attention. Some of these storms die out before making landfall and others veer away from the coast and dissipate at sea. However, in most years, several storms make landfall and are strong enough to be significant geological events, especially in terms of beach erosion and coastal flooding. Of particular interest are "intense" hurricanes (categories 3-5 of the Saffir-Simpson scale). These have the potential to cause substantial economic and environmental damage to the U.S. Atlantic and Gulf coasts.

Worldwide, the largest and most destructive coastal storms are tropical and extratropical cyclones that revolve around centers of low barometric pressure. Tropical cyclones, which include tropical storms and hurricanes, are smaller and more intense than extra-tropical cyclones and originate between latitudes 30˚N and 20˚S. They travel from east to west. Tropical cyclones form during the summer "hurricane season," when warm sea-surface temperatures, rain centers, and upper-level atmospheric circulation favor their generation.

Most cyclonic wind systems take several days or longer to mature into extreme storms because they rely on positive feedback mechanisms to become larger and stronger. Tropical cyclones are like heat engines that derive their energy from the warm water of the ocean. The intensity of tropical cyclones depends on sea-surface temperature and storm speed, assuming favorable conditions in the upper atmosphere. For example, slow-moving or stalled tropical cyclones may lose strength because upwelling brings cooler water near the surface and takes away their energy source. Fast-moving storms can lose strength by encountering a landmass or cooler water before reaching their full potential.

Tropical cyclones generate high waves and strong currents that are capable of eroding, transporting, and depositing large volumes of sediment in relatively short periods of time. Generally, large, long-period waves travel faster than the forward motion of the storm. These forerunners can inflict severe damage on nearby beaches and initiate beach erosion. Extreme wave heights are short-lived and are located near the storm centers.

You will use Hurricane Lili (2002) as a "case study" to learn more about tropical cyclones and their impacts.

WEB Stop 1 **Question 1**

1. When (year-month-day to year-month-day) did Hurricane Lili occur? Where did Hurricane Lili make landfall?

A coastal hazard assessment involves two different activities: characterization of ground conditions, and translation of that information into a hazard-vulnerability assessment. Hazard vulnerability depends upon the particular hazard being assessed. The natural coastal attributes that are considered to have the greatest influence on storm impact, as well as on long-term relative sea-level rise, are (1) dune height and continuity, (2) beach stability and width, (3) presence or absence of overwash zones, and (4) presence or absence of emergent offshore sandbars.

Coastal areas that have relatively low hazard potential feature high and continuous dunes, wide and stable beaches, no overwash zones, and the presence of offshore bars. The wide beaches and offshore bars cause waves to break and dissipate their energy, and the high dunes prevent the waves from overwashing the coast. In contrast, extremely hazardous areas lack high dunes and have narrow, eroding beaches that show numerous overwash zones. These areas are unsuitable for coastal development.

The U.S. Geological Survey (USGS) conducts post-storm surveys and research on anticipating how storms will alter the coastal landscape. The USGS has formed a partnership with the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) to obtain lidar (Light Detecting And Ranging) elevations and positions for the U.S. ocean coasts. Lidar technology is a rapid, cost-effective airborne method for obtaining large-scale accurate maps of beach and dune topography. This laser technology provides highly detailed topographic coverage in swaths about 500 m wide that are centered on the beaches and dunes. Lidar surveys conducted for the same area before and after a storm provide a means for measuring storm-induced erosion and deposition.

WEB Stop 2 **Questions 2–5**

Look at the graph that shows lidar profiles surveyed before and after Hurricane Lili.

2. What was the highest land elevation before (m), and after (m) the storm?

3. How far did the highest point on the barrier island migrate? (m)

4. How did the storm affect the barrier island?

5. Identify the storm impact level using the USGS classification of storm impact regimes.

Short-term Changes in Sea Level

During a tropical cyclone, water levels near the coast tend to be increased by the combination of low barometric pressure, strong onshore winds, and large breaking waves. The elevated water is known as a storm surge. Another factor that influences the magnitude of storm surge is the phase of the tidal cycle at the time when the storm affects the coast. (For example, if the storm hits the coast during high tide, this can allow the storm surge to reach higher than if it hit at low tide.)

WEB Stop 3 **Questions 6–7**

Use the Grand Isle, Louisiana tide gauge to determine the magnitude of the storm surge caused by Hurricane Lili (2002).

6. Using the dates (year, month, day) of Hurricane Lili, identify the maximum storm surge measured at the gauge. (m)

7. While studying the tide gauge data for Grand Isle, Louisiana, you may notice that there are two storm surges displayed on this plot, one on September 26, and the other on October 3. Note that Hurricane Lili made landfall in Louisiana on October 3. Make a hypothesis about what occurred on September 26.

(Hint: Check out the 2002 online map of Atlantic Tropical Cyclone Tracks.)

Storm flooding is actually even higher than the recorded water-level heights. This is because the tide gauges do not measure the waves that are superimposed on the storm surge or the increased water levels at the shore caused by the presence of waves, called wave setup (roughly 10% of the height of the breaking wave). In addition, waves induce a run-up that swashes up and down the beach face and can reach several meters above still water.

Long-term Changes in Sea Level

At many sites throughout the world, sea level is rising at an average rate of about 1.8 mm/yr. For one year, this vertical change in water level is minor and may not seem important. However, when the rise persists for decades or centuries, the cumulative rise in sea level can inundate broad, low-lying coastal areas. Further-more, the rise in sea level eventually causes waves to break higher on the beach during storms, forcing beaches to retreat inland.

At many coastal sites, submergence is the most important factor responsible for converting uplands or wetlands to open water. Submergence refers to permanent flooding of the coast caused by a rise in global sea level and/or subsidence of the land. How much land will be inundated as a result of sea-level rise depends partly on how fast the water is rising. It has been estimated that each year, global sea level rises about 1.8 mm as a result of a worldwide increase in water volume. This value, however, is substantially less than the total rise in relative sea level recorded at many individual tide gauges. Therefore, scientists have concluded that the remaining amount of relative sea-level rise is caused by land subsidence.

Not only is sea level rising in a relative sense at many coastal sites, statistical analyses of long-term tide gauge records also show that the present rates of relative sea-level rise are much greater than rates of submergence for the past few thousand years. This discrepancy between historical and geological rates of submergence has been interpreted by some as evidence that atmospheric warming (starting with the Industrial Revolution in the 1700s) is causing thermal expansion of the oceans and melting of mountain and continental glaciers.

WEB Stop 4 **Questions 8–10**

Use the tide gauge data to plot the mean annual water level in Grand Isle, Louisiana.

8. Describe the trend of a line drawn through the data set.

9. Calculate the long-term average rate of relative sea-level change. ____________ mm/yr

10. The long-term average global rate of sea-level rise is about 1.8 mm/yr. How does the rate of relative sea level change at Grand Isle compare with the global rate of sea-level rise?

11. Use the information you have compiled through the course of this exercise to construct an argument against someone building his/her vacation home on Grand Isle, Louisiana.

Your Name: **Date:**