

Environmental Geology Lab 6 – Coastal Hazards

In the continental United States there are two fundamental types of shorelines. Tectonically passive margins that have low relief and consist of smooth sandy beaches, which are present on the Atlantic and Gulf coasts. Tectonically active margins with localized uplift associated with earthquake-prone areas, such as the Pacific coast, where the coastline has a predominately rocky character. The main hazard that impacts tectonically passive shorelines comes from tropical cyclones or low pressure systems. The main hazard along tectonically active shorelines comes from tsunamis.

Occasionally, the South Texas coastline is struck by a tropical storm or hurricane, formally known as a tropical cyclone, that makes landfall in this region. The textbook shows the probability of a hurricane and a major hurricane striking the South Texas shoreline. Hurricane season begins on June 1 and extends through November 30 with a peak in tropical activity around mid-September.

Tropical cyclones are classified based on sustained wind speed as indicated below.

Tropical Depression	Winds < 39 mph
Tropical Storm	Winds Between 39 to 73 mph
Hurricane	Winds > 73 mph

Additionally, hurricanes can be further classified based on their intensity through the Saffir-Simpson scale (see textbook). Category 1 and 2 are minimal hurricanes; whereas category 3 to 5 storms are referred to as major hurricanes.

To understand the occurrence of storms like hurricanes, and for that matter fair, sunny weather, we need to learn about how air moves within the atmosphere. The movement of air is driven by differences in atmospheric pressure that occur within the atmosphere. Most people that have even casually glanced at a weather map from the television or internet notices the presence of areas of high pressure (**H**) and low pressure (**L**) depicted on weather maps. Hurricanes are areas of intense low pressure. Winds spiral in toward the center of the low-pressure system in a counterclockwise fashion (in the northern hemisphere). Note that you will only see an eye and spiral rain bands with a well-developed hurricane (Figure 1). The eye is where there are minimal winds and the skies can actually be clear. Conversely, the most intense rain band and winds occur next to the eye in the eye wall, which are the band of thunderstorms present immediately outward from the eye (Figure 1). Storm intensity is the greatest in the eye wall located in the right front quadrant of the system (Figure 1). This area is immediately to the right of the movement of the storm where the velocity of the storm movement is added to the winds spiraling inward causing the greatest damage in this sector.

Tropical cyclones (tropical storms and hurricanes) have four hazards that can affect the immediate coastline and in some cases can influence areas that are several hundred miles inland, like Laredo. Along the immediate coast the greatest danger are from **storm surge** and **strong winds**.

Storm surge has the greatest potential to cause damage along the immediate coastline. Hurricanes can pile up the waves up against the shore particularly in the front right quadrant of the storm where the wind speed is greatest. Additionally, the low pressure of the hurricane can actually pull water up into the atmosphere locally rising sea level up to 1 meter. Finally, tides can play a role with the worst case scenario associated with a storm that makes landfall during high tide. In today's lab you will examine potential storm surges for hurricane that hits Cameron County, where Brownsville is located. The National Weather Service has developed the SLOSH program that can model storm surge maps. We will look at inundation resulting from a category 1, 3, and 5 storm.

The SLOSH figures to be provided do not depict the entire extent of flooding as it only considers flooding from coastal storm surge and does not account for freshwater flooding from rivers. Therefore, the extent of flooding will likely be worse than that depicted in figures provided.

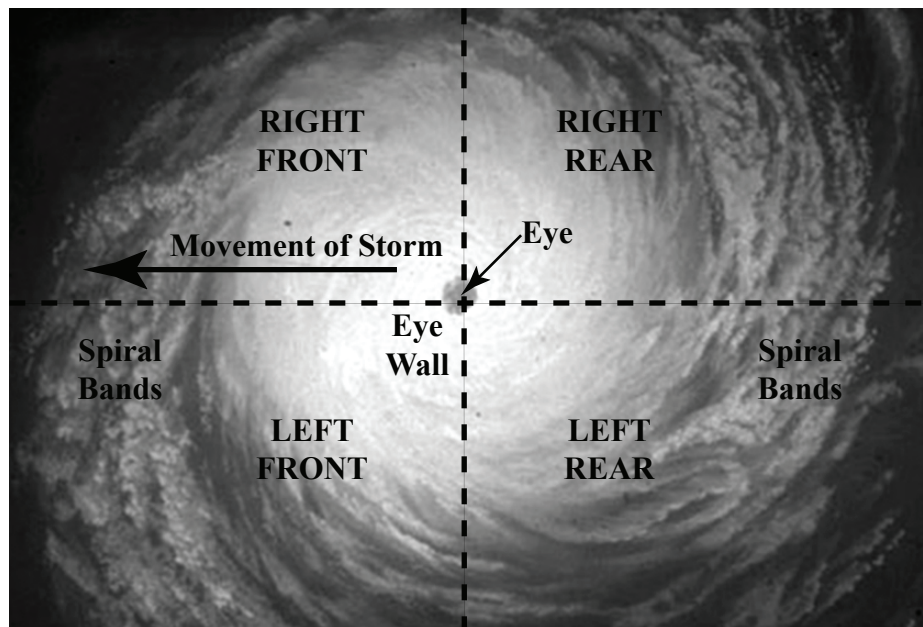


Figure 1. The features of a hurricane with its four quadrants illustrated.

Strong winds can cause significant damage right along the coast. However, once a tropical cyclone makes landfall they rapidly lose their wind strength over land because the friction generated by rough land surface impedes winds. Therefore, if a hurricane makes landfall in South Texas by the time it reaches Laredo, 150 miles inland, the winds would be down to tropical storm strength. We will make some calculations to determine the relative strength of minimal tropical storm winds versus winds from a category 5 hurricane later in this lab.

Therefore, in areas away from the immediate shoreline the hazards from tropical cyclones include **freshwater flooding** from heavy rains and occasional **tornados**.

You need to realize that the danger is not over once a hurricane makes landfall. Even tropical storms and depression can cause acute flooding and lost of life. The best example from recent history includes flooding in Houston in 2017 caused by Hurricane Harvey. This storm meandered over Houston for almost one week and in some places over 80 inches (2.3 meters) of rain fell causing flooding the shut the city down for weeks. Another example was back from 1954 when a tropical cyclone made landfall in northern Mexico dumping so much water on the Rio Grande basins that the Rio Grande had as much discharge as the Mississippi River has on average! We will examine the rainfall from the 2005 storm Hurricane Dolly and calculate how much rainfall is generated from a small watershed near Laredo.

Finally the instability associated with a land-falling hurricane can generate tornados. Remember that winds close to the surface slow but not at higher levels in the atmosphere. This condition can lead to vertical wind shear that favors tornadonic development. We will examine the tornados that were generated by Hurricane Dolly.

QUESTIONS:

1. Examine page 1 and Figure 1 and indicate in which quadrant will the winds and rainfall be the greatest.

2. What is the intensity of rainfall and cloud cover associated with the center of the storm?

3. In what direction do hurricanes in the northern hemisphere rotate _____ Clockwise or Counter clockwise

4. If a hurricane that is moving from east to west across the Gulf of Mexico makes landfall just south of Brownsville where will the greatest damage occur?

In Mexico to the south of the eye or To the north in the US north of the eye

5. During which time of year in South Texas are we most likely to get heavy rain from tropical storms and hurricanes _____

6. Describe what happens to the wind velocities and precipitation intensity of a tropical cyclone once it makes landfall.

Examine the SLOSH storm surge maps provided by your instructor indicating the impact of a category 1, 3, and 5 storm hitting Cameron County and answer the questions below.

7. Is it necessary to evacuate Brownsville if a minimal category hurricane looks like it will closely approach this region?

8. Is it necessary to evacuate Brownsville if a major hurricane looks like it will closely approach this region?

9. Examine the US Map in the back of the classroom. Which route would be the best one to use in evacuating Brownville and the valley in general? Your evacuation should end at a major population center that is within 250 miles of Brownsville. Do not take a route close to the coast that could be affected by the storm. Provide sufficient detail so that you could give directions to your family to get them out of harms way.

10. How wise is it to buy property on South Padre Island given the frequency of tropical cyclones in this region?

11. High winds associated with tropical cyclones have a great potential to wreck buildings and structures. The force exerted on these buildings obviously increases as velocity increases as indicated by equation #1 below:

$$(1) \text{ Force } \propto (\text{Wind Velocity})^2$$

Compare the force exerted on structures by a minimal tropical storm (40 mph), a minimal hurricane (75 mph), and a category 5 hurricane (180 mph). Complete the table on the next page.

Type of Storm	Wind Velocity (mph)	Normalized Wind Velocity *	Force Compared with Tropical Storm
Minimal Tropical Storm	40	1	1
Minimal Hurricane	75	1.875	
Category 5 Hurricane	180		

* Normalized Wind Velocity is Normalized to Tropical Storm Wind Velocity

$$\text{Normalized Wind Velocity} = \frac{\text{Storm Wind Velocity}}{\text{Tropical Storm Wind Velocity}} \\ (40 \text{ mph})$$

$$\text{Force Compared with Tropical Storm} = (\text{Normalized Wind Velocity})^2$$

For Example the Minimal Hurricane

$$\text{Normalized Wind Velocity} = 75 \text{ mph} / 40 \text{ mph} = 1.875$$

$$\text{Force Compared with Tropical Storm} = (1.875)^2 = \text{????}$$

12. In your own words contrast the extent of wind damage to a beach house associated with a minimal tropical storm versus a category 5 hurricane.



Figure 2 (previous page). Storm track of Hurricane Emily from July 2005. Green indicates tropical depression, yellow means tropical storm, and red and orange denotes hurricane strength. Modified map from the Historical Hurricane Tracks website (NOAA Coastal Services Center; <http://hurricane.csc.noaa.gov/hurricanes/index.html>)

13. Identify the date in which Emily - use Figure 2 above

First Attained Tropical Depression Strength _____

First Attained Tropical Storm Strength _____

First Attained Hurricane Strength _____

Made First Landfall in Yutacaan _____

Made Second Landfall in northern Mexico _____

14. Indicate the direction in which Emily is moving towards.

15. Precisely describe what happened to the intensity of Emily upon making its second landfall in northern Mexico.

Examine Figures 3 and 4, which indicate the amount of rainfall that fell in South Texas and answer the questions below that deal with flooding associated with heavy rainfall. The gray box indicates the location of a Webb County ranch from which an average rainfall value needs to be determined.

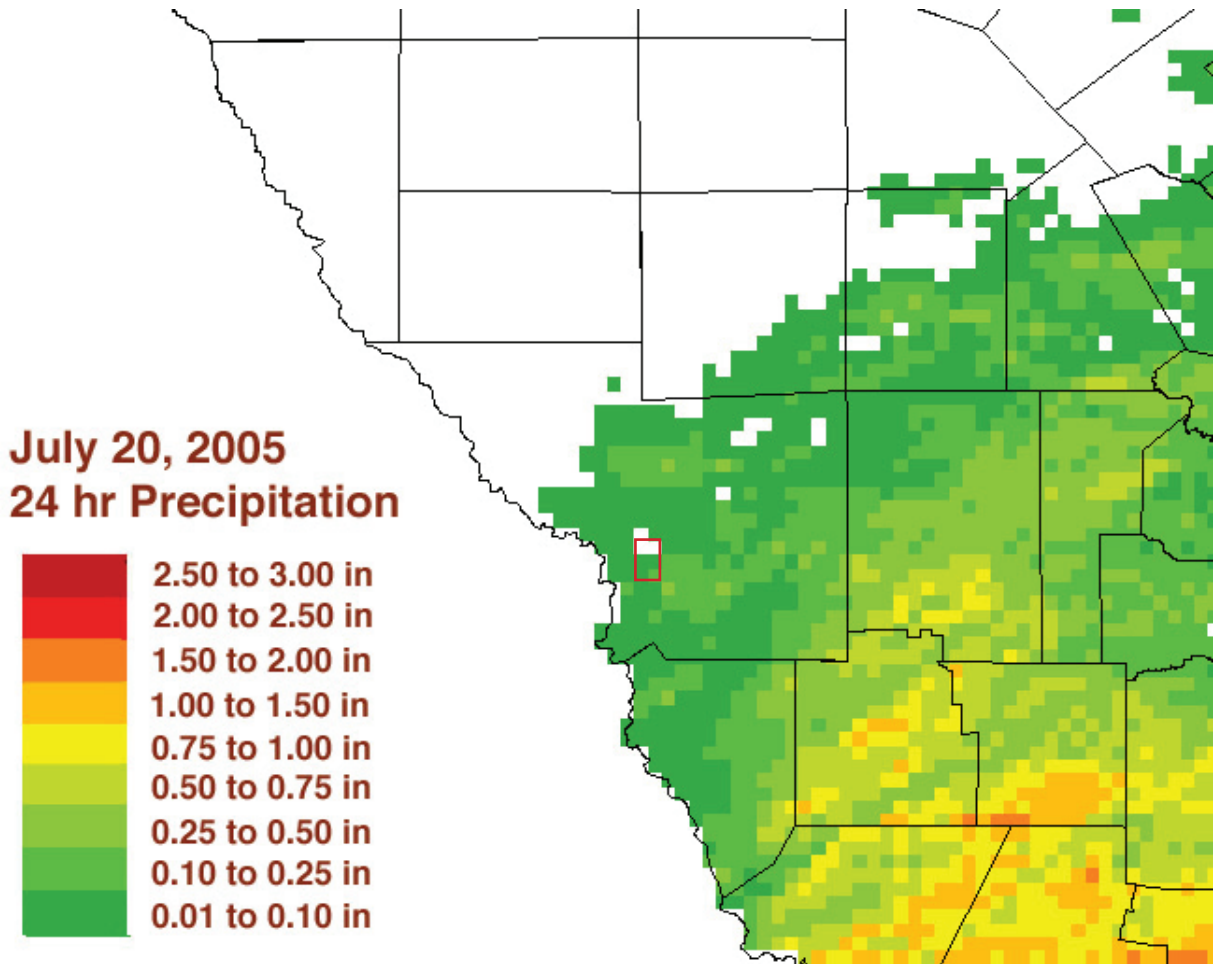


Figure 3. Radar estimated precipitation from TAMIU service area for July 20, 2005.

16. Does the rain shield generated by Emily completely cover the TAMIU service area July 20?
What about on July 21?

17. How much rain did gray box get on July 20 and 21? Note difference in scales between two dates. Also, total up the values for both of these dates. There are a total of six pixels in the affected ranch. Also, select the mid-point of the range of precipitation values.

July 20 _____ in

July 21 _____ in

Total _____ in

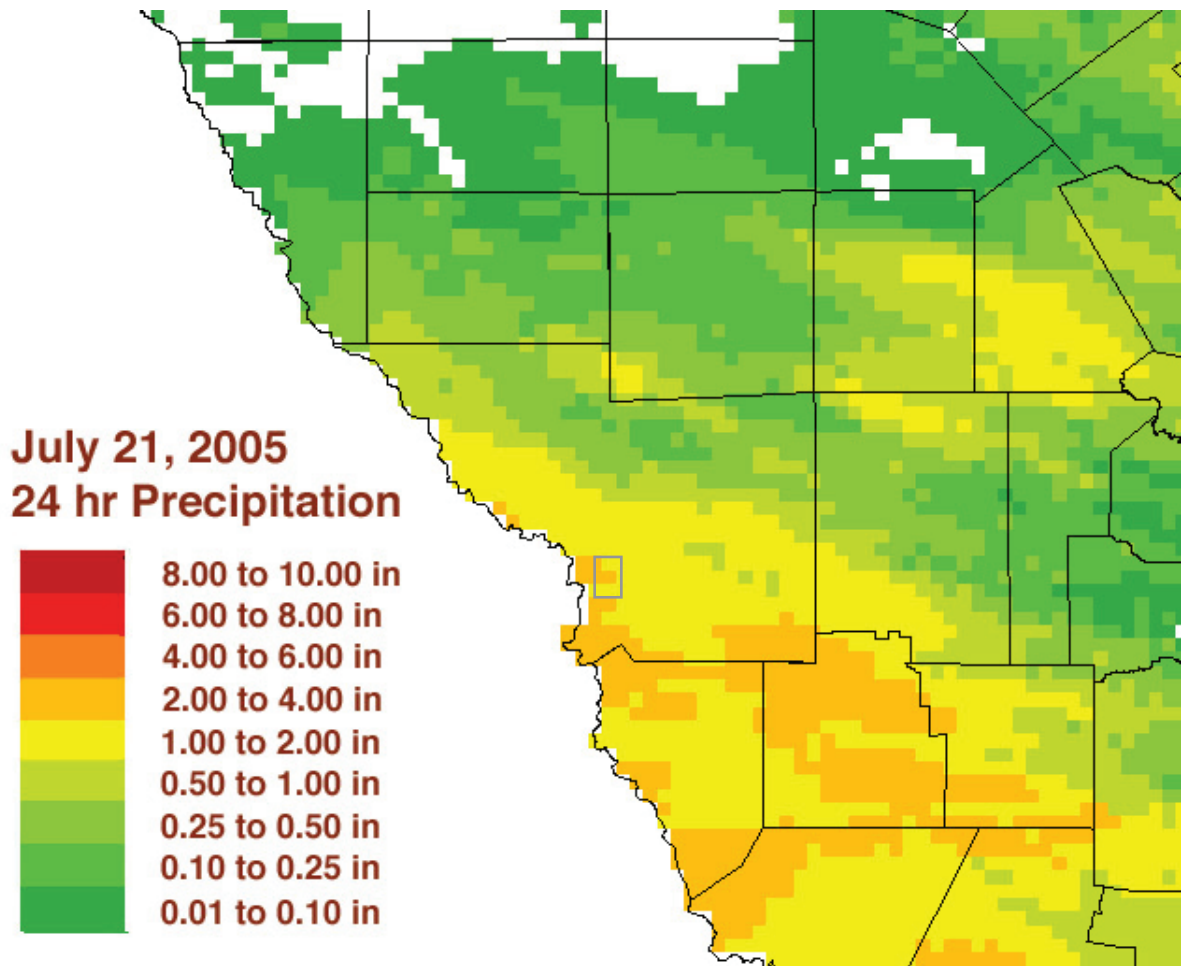


Figure 4. Radar estimated precipitation from TAMIU service area for July 21, 2005.

18. Convert total precipitation value in inches into millimeters by multiplying it by 25.4.

19. Based on your understanding of the movement of Emily explain what causes the radar estimated precipitation for July 20 to be different from July 21.

20. If the PET was 3 mm for July 20-21 determine the amount of discharge produced from Emily over the Webb County ranch (gray boxes on Figures 3 and 4). Remember that if $P > PET$ then $Q \text{ (mm)} = P \text{ (mm)} - PET \text{ (mm)}$.

21. Determine the amount of discharge (in cms) generated from the Webb County ranch from Emily.

(a) Convert discharge (Q) value in mm to meters

$$Q \text{ (m)} = 0.001 \times Q \text{ (mm)} = \underline{\hspace{2cm}} \text{ m}$$

$$\text{Area (m}^2\text{)} = 24,000,000 \text{ m}^2$$

(b) convert Q to a volume measurement (in m^3)

$$Q \text{ (m}^3\text{)} = Q \text{ (m)} \times \text{Area (m}^2\text{)} = \underline{\hspace{2cm}} \text{ m}^3$$

(c) convert Q into cms

$$Q \text{ (m}^3\text{)} = Q \text{ (m)} / 86,400 \text{ sec} = \underline{\hspace{2cm}} \text{ cms}$$

22. Compare answer in question 21 with the discharge values from Labs 1 and 2. Did flooding likely occur associated with Emily especially considering when about 9 cms would cause a two-year flood on this ranch. Explain your answer in detail.

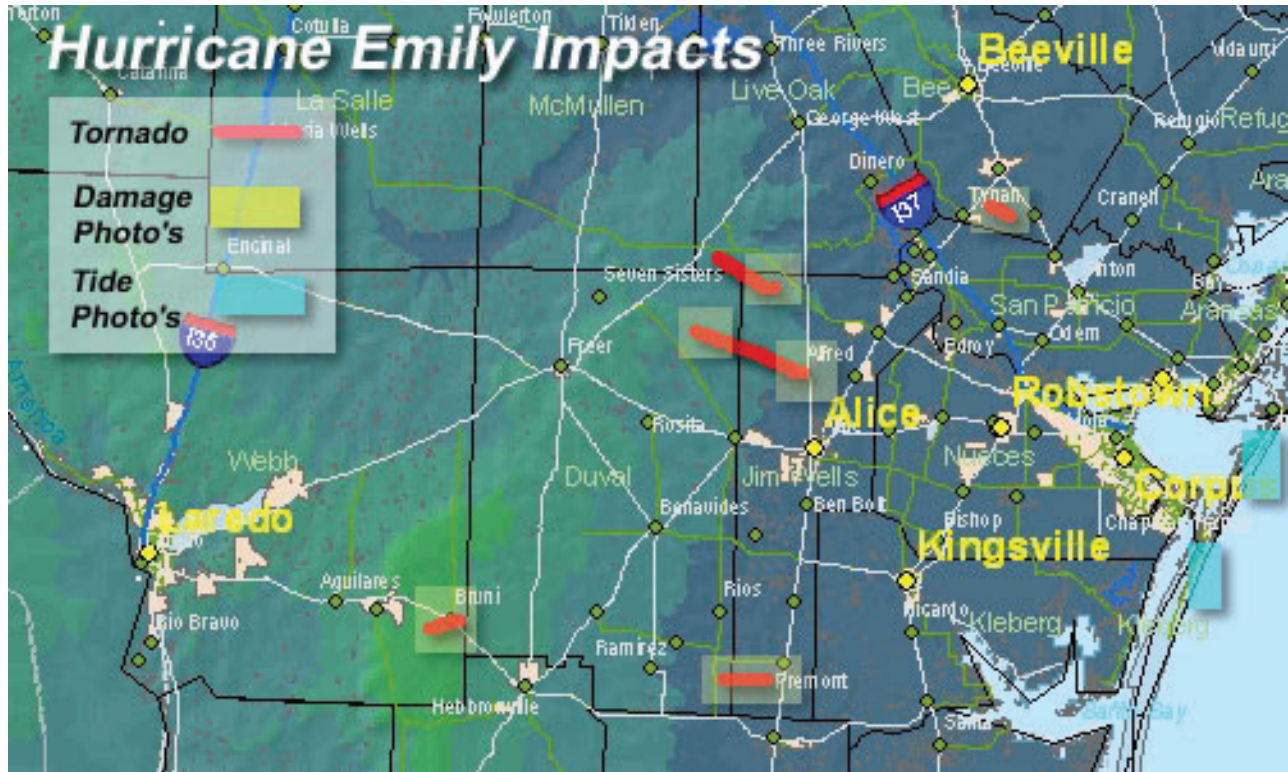


Figure 5. Overview of impacts from Hurricane Emily in South Texas. From NWS website.

23. How many tornados were produced by Emily in South Texas. _____

24. In the Laredo area which hazard associated with Emily likely caused the most damage. Justify your answer.

The phenomenon we call a tsunami is a series of large waves of extremely long wavelength and period usually generated by a violent, impulsive undersea disturbance or activity near the coast or under the ocean. When a sudden displacement of a large volume of water occurs, or if the sea floor is suddenly raised or dropped by an earthquake, big tsunami waves can be formed by forces of gravity. The waves travel out of the area of origin and can be extremely dangerous and damaging when they reach the shore.

Tsunamis are mostly the result of shallow focus, submarine earthquakes that cause displacement of water. More rarely tsunamis can be the result of submarine landslides, volcanoes, or even an asteroid impact in the ocean. Tsunamis are not associated with tides and are misnamed when referred to as “tidal waves.” **Tsunamis pose a threat to mostly Pacific type shorelines.** However, landslide disturbances can also produce tsunamis in the Atlantic basin as we will learn in today’s lab (Figure 6). To understand tsunamis you need to learn the wave equation:

(3) Wave Velocity (km /hr) = Wavelength (km) / Period (hr)

Wavelength is the distance between successive wave crests

Wave Period is the time it takes successive wave crests to pass a single point.

QUESTIONS:

25. If a tsunami had a wavelength of 210 km and a period of 0.3 hours determine the velocity of a tsunami in kilometers per hour. How much time would it take a tsunami to travel the approximately 1000 km from the site of the landslide to reach the Texas coast?

$$\text{Wave Velocity (km /hr)} = \text{Wavelength (km)} / \text{Period (hr)}$$

$$= \underline{\hspace{4cm}}$$

$$\text{Time (hours)} = \text{Distance (km)} / \text{Wave Velocity (km /hr)}$$

$$= \underline{\hspace{4cm}}$$

26. Determine distance traveled (in km) for the following times after the landslide event.

15 minutes

30 minutes

45 minutes

1 hour

1 hour, 15 minutes

27. Plot the distances from question 26 on Figure 6 using a compass. Stop the circle when they hit land.

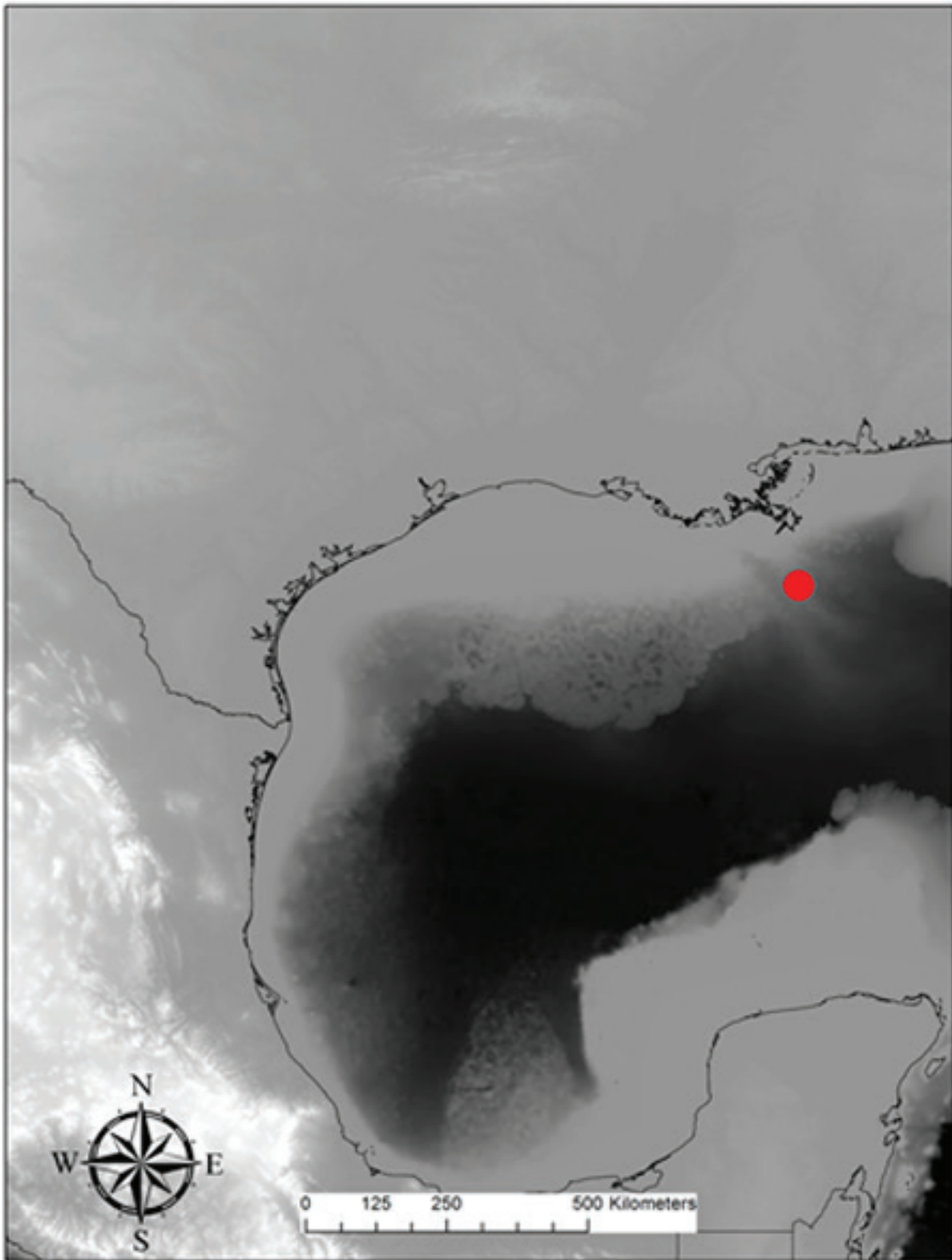


Figure 6. Elevation map of the Gulf of Mexico. Site of underwater landslide indicated by red dot.

Tsunami waves can flood or inundate low lying coastal areas as illustrated in Figure 7. Tsunami inundation is the horizontal, inland penetration of waves from the shoreline. Flooding can extend inland by 300 meters (~1000 feet) or much more along low lying coastlines, covering large expanses of land with water and debris. Inundation distances can vary greatly along the shorelines, depending on the intensity of the tsunami waves, the undersea features, and the land topographic elevations. One coastal community may see no damaging wave activity, while another nearby community can be attacked by large and violent waves. When the tsunami reaches the coast and moves inland, the water level can rise many meters. The first wave may not be the largest in the series of waves. Examine Figure 7 on the next page and answer the following questions related to the landfall of tsunamis

QUESTIONS:

28. Are all coastlines affected in a similar manner by the arrival of a tsunami?

29. Define the term run-up.

30. Define the term inundation limit.

31. On Figure 8 draw two lines to represent the expected 5 and potential 10 meter run ups in the area of Corpus Christi.

32. What major South Texas cities need to be evacuated immediately.

33. Determine the inundation limit (in kilometers) for the Corpus Christi area using the graphic scale provided. Assume a 5 meter run up.

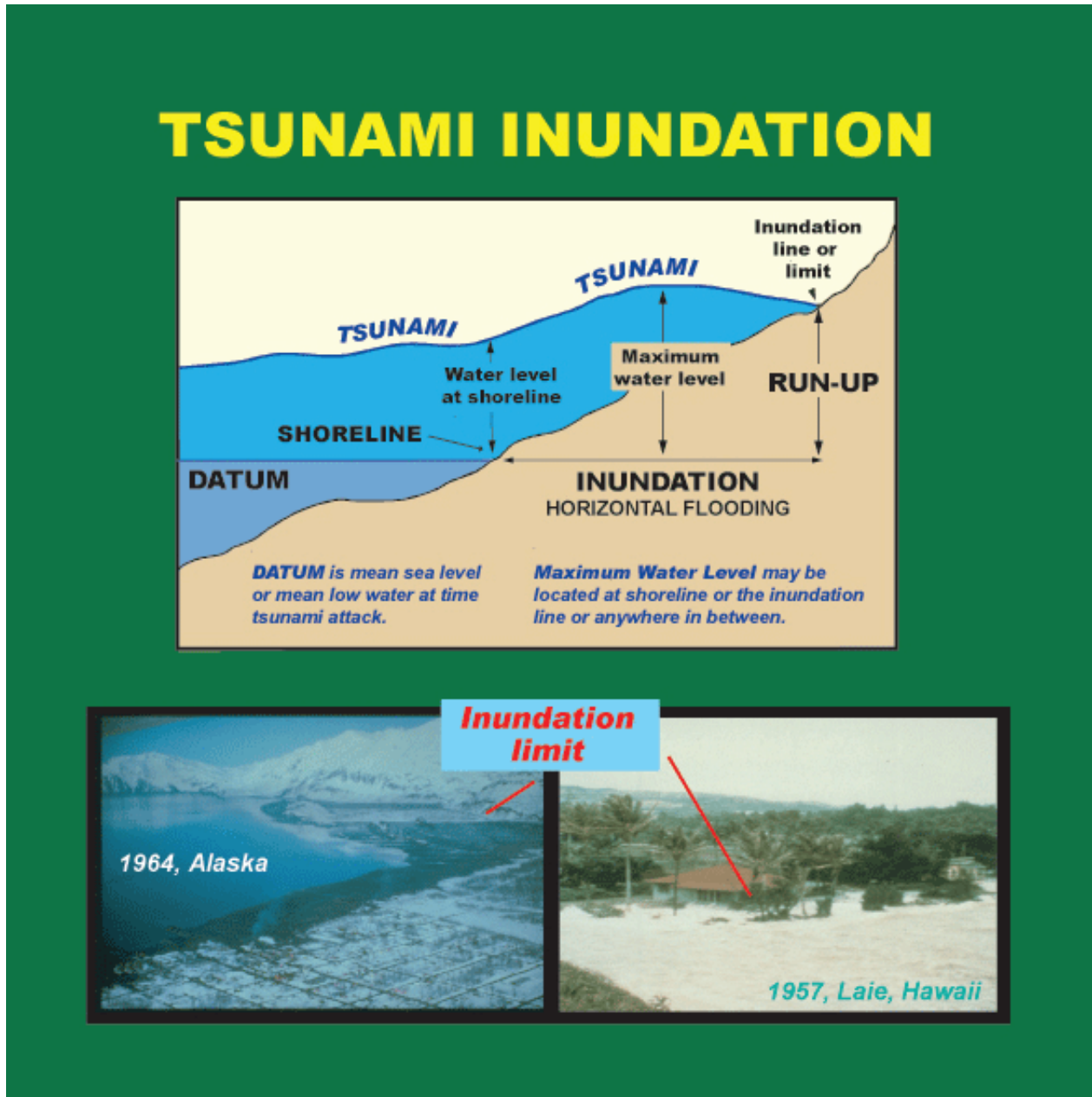


Figure 7. Tsunami inundation terminology.

You are in the State's Emergency Operations Bunker in Austin when the underwater landslide occurs. Waves inundates Louisiana in a matter of minutes. You have a little more than an hour to organize Texas's response to this threat. Based on the characteristics of the tsunami NOAA indicates that a 5 meter run-up can be expected. But, you know that tsunamis can affect shorelines in different ways. You decide to set a safe maximum potential inundation limit at an elevation of 10 meters. Answer the questions below to help organize Texas's response. Work quickly as lives are on the line.

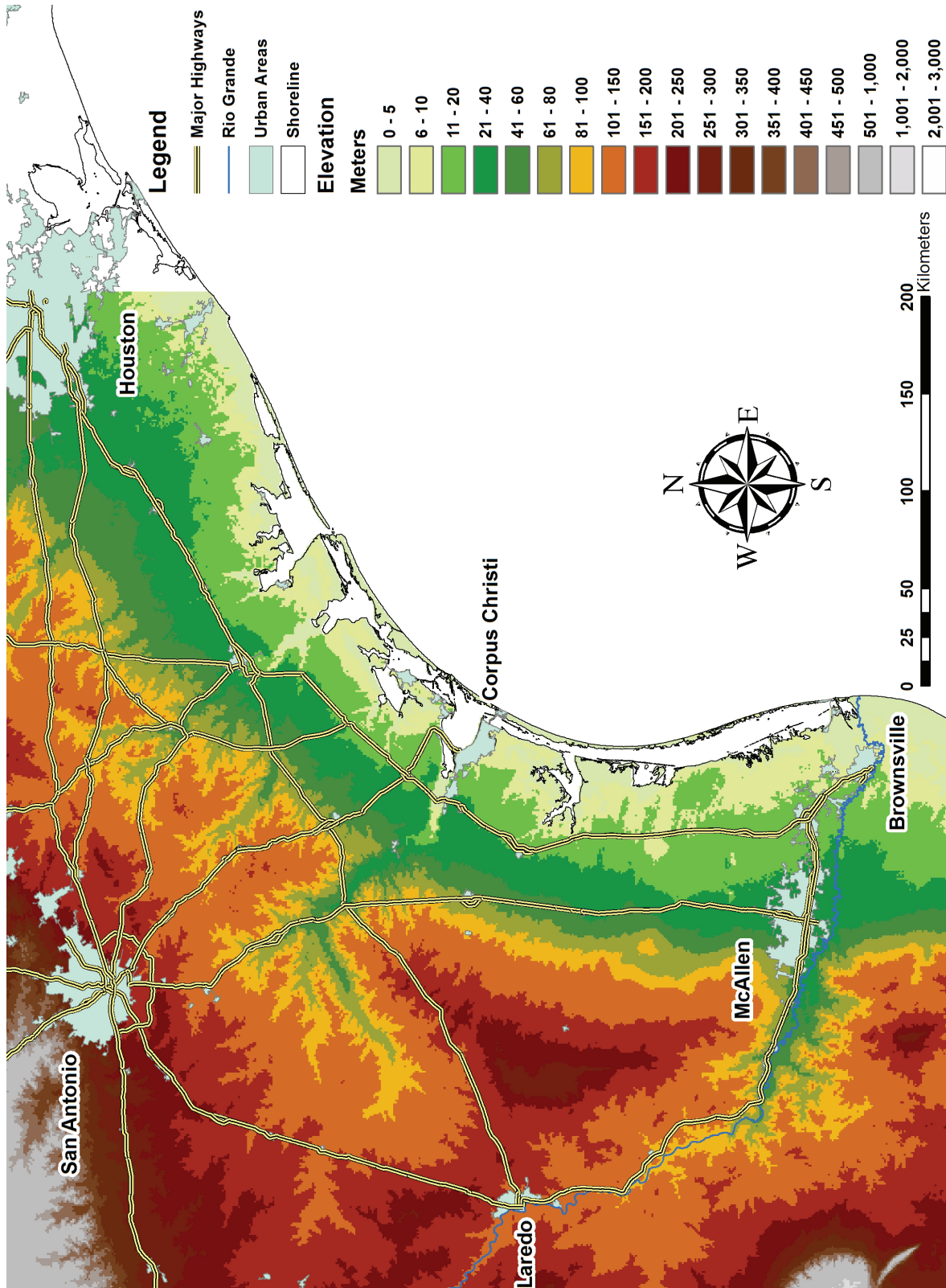


Figure 8. Elevation map for coastal Texas.

34. If you live in Brownville, first good luck. If you are evacating what major highway would you avoid. Use US Map in back of the lab to find highways.

35. What problem would happen if many from McAllen decided to evacate as well. Do the people from this city need to move based on your analysis of the tsunami.