The Education Program at the
New Jersey Sea Grant Consortium

22 Magruder Road, Fort Hancock, NJ 07732 (732) 872-1300
www.njseagrant.org

UNDERSTANDING STORM SURGE

ACTIVITY #6 – SURGE OF THE STORM

http://secoora.org/education-outreach/hurricanes/

OVERVIEW

Storms create winds that create waves. Storm waves can be unrelenting along the shoreline, pushing water very far up onto land and creating storm surge. Students will examine how different shapes and slopes of shorelines are affected by storm surge.

MATERIALS

- Plastic shoe boxes or other long rectangular-shaped containers
- Clay and/or sand
- Water, blue food coloring, and/or dish soap for thickener
- Monopoly houses, Legos, sticks, rocks, or cardboard to represent houses and other man-made structures on land
- A wind-wave source, such as a wood or plastic paddle almost as wide as the container
- Topography cards (see below) for students to choose from

PROCEDURE

1. Divide students into groups of 2-4. Ask each group to select a topography card (included at the end of this lesson). These cards will instruct students on how to mold the clay to create the land/beach area in their container to observe how different land forms are affected by storm surge.

2. Ask each student team to mold clay into a beach area according to the directions on their topography card. **Card options are: gentle sloping beach** with a rise (high) of 4 cm and a run (long) of 16 cm; **moderate sloping beach** with a 5 cm rise and a run of 10 cm; **steep sloping beach** with a 6 cm rise and a 6 cm run**; convex beach; concave beach; estuary with meandering river or barrier beach island.**

3. In a separate container create “ocean water” by mixing equal parts water with a few drops of blue food coloring and a thickener, such as dish liquid, hair gel, or shampoo. The thicker liquid will help students better visualize what happens on land during a storm surge since the thickened liquid will not retreat as fast as water usually does.

4. Slowly add the “ocean water” to the empty side of the container. Add about 1 cm of water. Students may add more if needed to just reach land, surround the barrier island, and/or reach the mouth of the river or estuary that they molded in their container.

5. Students can add objects along the water’s edge to represent man-made structures, such as houses, hotels, cars, etc.

6. **Option 1:** Place toothpicks every centimeter from the water’s edge where the water meets the land, moving perpendicular up onto the land to the edge of the container. Place the first toothpick at 1cm and will continue adding toothpicks at 1 cm intervals to the edge of the container. With the toothpicks in place, students will be able to measure the distance and height that the water level reaches at different points along the landform based on the watermarks left on the toothpicks. Students may create a graph with the measurements of the height of the storm surge as the storm surge moved “inland.”

7. **Option 2:** On the side of the container, use an erasable marker and ruler to place a mark every centimeter from where the water meets the sand all the way up the landform to the top of the container. The mark at the edge of the island should be the 0 mark. Label each mark 0, 1, 2, 3, etc. where each mark represents one centimeter. Students will make observations about how the surge moves inland and how much land is eroded during the storm.

8. Ask students to create mild storm waves by pushing a paddle in the water very gently towards land. Students should make a wave about every 1-2 seconds for 30 seconds and observe what happens to the land areas. Record the distance these normal waves travel inland in the data table on the worksheet in Observations #1. Answer questions 2 & 3.

9. **Read this part carefully before beginning!!!** Next ask students to create a hurricane storm surge. To do this, they will need to push water from the ocean onto land. Waves should be made as fast as possible or at least every ½ second so the waves and water are not allowed to flow back down into the ocean. Be sure to PUSH the water up onto the land, not just splash. This demonstrates the same intense waves produced

during a surge. Answer observation question #4. Answer the remaining observation questions and prepare your conclusion.

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Student worksheet/ data table

Name of Topography Card: _____

Type of disturbance	**Distance felt inland**
Mild Storm Waves	
Harsh Storm Wave- Storm Surge	

1. Describe what happened in your model when you created mild storm waves.

2. Which area of your model was most affected by the mild storm waves? Explain why this happened.

3. Explain how the slope or shape of the land impacted the areas affected by waves.

4. Describe what happened in the model when you created harsh storm with storm surge. Explain what happened inland and the height of the surge observed on your toothpicks.

5. If you had an estuary or river form in your container, explain how the harsh storm (which is formed in the ocean) impacted the inland shallow water areas.

6. Are estuaries and rivers also impacted by storm surge?

7. Was any area of your model “safe” from the storm surge during your harsh storm”? Explain your answer.

8. If an evacuation had been ordered, how far should the people travel from the shore in order to be out of harm’s way? Support your answer using ideas from the model and further research if necessary.

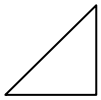
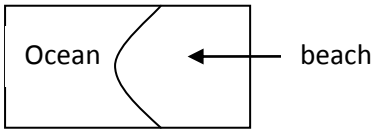
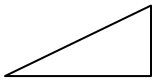
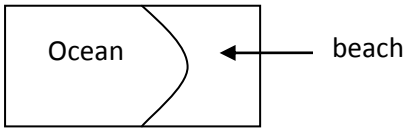
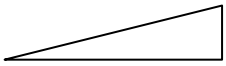
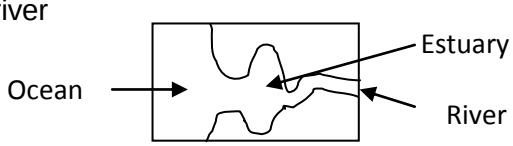
9. What recommendations would you make to a developer who is interested in building on coastal properties?

10. Describe how the effects of a storm surge can impact the lives of the people and the economy of the community.

Conclusions:

Share observations and worksheet answers made for each topography card. Discuss what a storm surge is, how it is produced, and how it could impact humans. Discuss with the other groups with different land forms how storm surge impacted their models: How did storm surge affect gentle slopes and low lying areas along the coast? How did the storm, which originated in the ocean, impact estuaries and rivers near the coast?

TOPOGRAPHY CARDS

Steep slope or cliff- 6 cm high, 6 cm long (side profile) 	Concave beach 
Moderate slope 5 cm high, 10 cm long (side profile) 	Convex beach 
Gentle slope- beach 4 cm high, 16 cm long (side profile) 	Estuary with a gentle slope and meandering river 

Extensions:

Storm Surge can be difficult to predict because storms can change at any time, making it difficult for meteorologists to predict with high probabilities. Wind direction, speed, storm intensity, storm size, and actual landfall can make a big difference between 20 feet of storm surge versus none, or evacuating hundreds of people versus not doing so. Ask students to create a landscape with varying slopes and landforms. Ask students to create wind using a straw at different locations and at different intensities and angles towards the shore. Ask students to predict where they may get the highest surge on their landscape and in which direction wind needs to blow from in order to create the biggest surge.

Ask students to hypothesize and then experiment with their models to determine how the impact of storm surge might be reduced. Students may think of ways humans might build structures to reduce impact or how natural land forms, such as salt marshes or dunes, may reduce the impact of storm surge.

Ask students to do the experiment again but add another ½ or 1 centimeter of water to represent a storm surge impacting the coast during high tide. Have students report and discuss how storm surge and tides can increase the impact of the surge along the coast.

Sea levels are rising and scientists predict that sea levels along the coast of New Jersey may rise ½ meter to 3 meters within the next 20 years. Ask students to raise the sea levels in their containers by 1, 2, or 3 centimeters and do the experiment again. Report the differences in how storm surge impacted the land forms with a raised sea level(s).

Further Explanation:

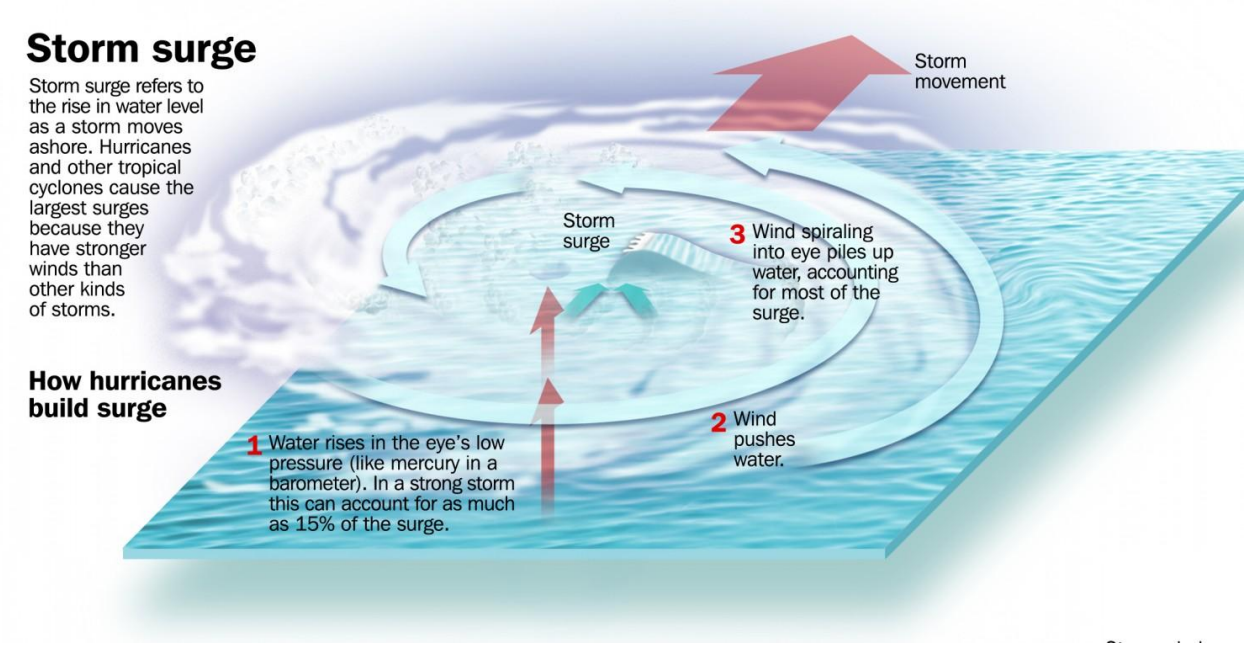
The main factors that create a storm surge are:

1. A low pressure system that causes water levels to rise because less force is being exerted onto the water.

2. The intensity of the storm forming strong winds. The intense wind piles water up as it reaches land and creates relentless waves, which do not allow water to retreat back into the ocean. This raises sea levels and pushes water inland. In this way, water can spread hundreds of miles inland during a storm surge. This also creates waves that can create a surge of water well before a storm even reaches land.

3. The spiraling of strong winds around a low pressure storm, which pushes water into the center of a storm. In Deep Ocean this water sinks, but when the storm reaches shallow water, it cannot sink. This creates a high mound of water that raises the sea levels and results in storm surge flooding on land.

(AMS Weather Book, American Meteorological Society)



FACTORS THAT INFLUENCE SURGE HEIGHT AND AMOUNT OF INUNDATION

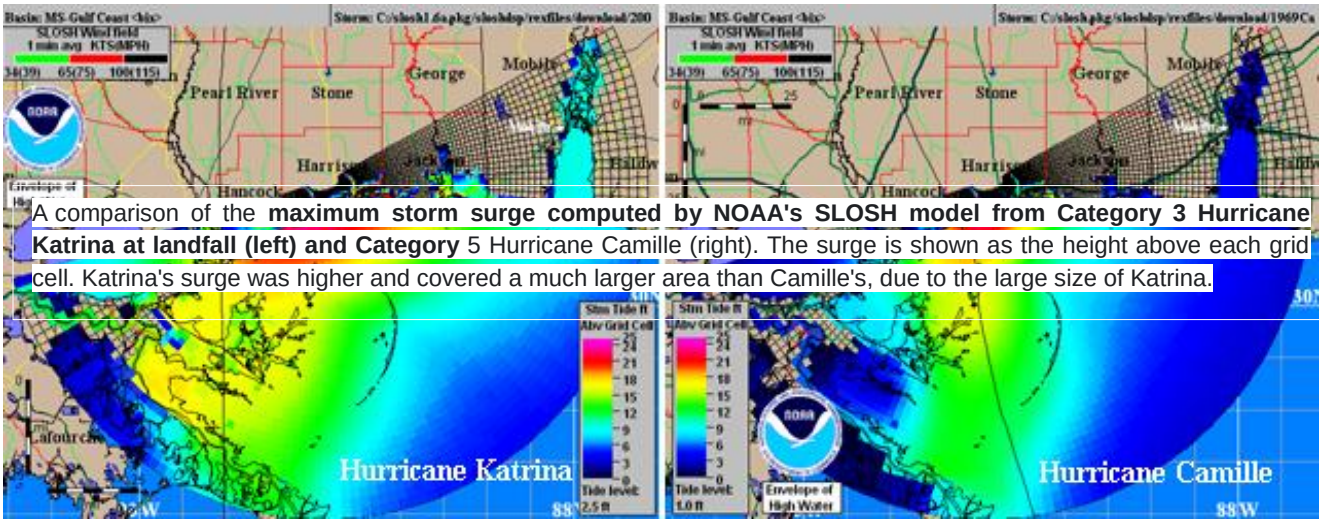
While these three main factors create storm surge, every surge is different. There are many other factors that influence surge height and amount of inundation, such as:

- **Storm size:** This is measured by its **Radius of Maximum Winds** (RMW), which is a measurement from the center of a storm to the band of its strongest winds; it can also be called the eye wall of a hurricane. This band of wind is almost like a cylinder cup that has formed inside the storm: the strongest winds are the actual walls of the cylinder cup that turn in a circular motion very fast, and the empty middle is the calm eye or center of the storm.

  Meteorologists classify a hurricane using the Saffir- Simpson wind scale, giving a storm a label of Category 1, 2, 3, 4, or 5 based on wind speed. A Category 5 hurricane will have super high speed winds tightly wound together, making the actual storm size or RMW smaller so there are high wind speeds but less wind overall, which will decrease the storm surge. A Category 3 hurricane will have decreased wind speeds, but this allows the storm to spread out and increase in size (but not intensity). This will increase the RMW and increases the storm surge. In a Category 3, the winds might not be as strong but there is *more* wind, and more wind will cause *more* water to be displaced and

rise into the center of the storm, which will increase storm surge when the hurricane reaches land.

Camile was a Category 5 hurricane with 190 mph winds that hit Pass Christian, Mississippi in 1969 and created a storm surge of 22.6 feet. Katrina was a Category 3 hurricane with 130 mph winds when it hit the same area in Pass Christian Mississippi in 2005 and created a 27.8 ft storm surge. Katrina created a higher storm surge because it was a larger storm with more wind. Hurricanes Camile and Katrina show that higher category hurricanes do not necessarily produce higher storm surges, so the amount of a storm surge from a hurricane cannot be based on the Saffir- Simpson Scale.



A comparison of the **maximum storm surge computed by NOAA's SLOSH model from Category 3 Hurricane Katrina at landfall (left) and Category** 5 Hurricane Camille (right). The surge is shown as the height above each grid cell. Katrina's surge was higher and covered a much larger area than Camille's, due to the large size of Katrina.

- **The shape of the continental shelf (sea floor):** Surge builds up more strongly if the slope of the sea floor at the coast is shallow. If the sea floor has a steep slope or if fringing reefs are present, the surge will be less because the water isn't able to reach up and onto land as easily.

Surge animation with shallow continental shelf
(Click on Image to Play Video)

Surge animation with steep continental shelf
(Click on Image to Play Video)

- **The shape of the land**: Land elevation, slope, and other local land features will be impacted by surge differently. Areas with gentle sloping beaches, shallow water, and low level land areas, such as marshes, will see the most storm surge. The location of the mouth of estuaries, inlets, and rivers also will be impacted differently by storm surge.

- **Storm speed**: The quicker a storm hits land, the faster the surge water will pile up. Also the faster the storm, the more powerful the winds and waves will become. As these waves reach shallow water and land, they grow even larger. These large waves push water even further onto land. Large breaking waves along the shoreline are powerful enough to knock down houses, destroy roadways, and wash away land.

- **Angle of approach:** A storm hitting land in a perpendicular direction will have a much harder impact than if it hits at a parallel or oblique angle. If the angle of the storm is a direct hit into the mouth of an estuary, inlet, or river, the surge will be amplified as these areas will funnel in water and intensify the storm surge