RISING WATERS

Pre-Visit Activity 2: Computer Models

Directions: Please read the following pages and answer the discussion questions at the end of each section on the provided Answer Sheet on the last page.

The best way to predict the storm surge is by using a computer model. These models have been developed by scientists and engineers, and they include our best understanding of how a storm can interact with a coastal region to create a storm surge. With information about a storm's strength and track, these models can **simulate** how it will cause flooding.

In the U.S., there are two models that are widely-used to predict storm surge: **SLOSH** (Sea, Lake, and Overland Surges from Hurricanes), and **ADCIRC** (ADvanced CIRCulation). Both models can predict the rise in water levels in the coastal ocean due to storms.

SLOSH is the operational model used by the National Hurricane Center (NHC). It is very fast -- a SLOSH simulation can be completed on a laptop in a few minutes, and hundreds of SLOSH simulations can be completed during each storm advisory. This speed allows its predictions to be useful by emergency managers and decision-makers during a storm. SLOSH separates the U.S. coast into 32 grids, which are centered on inlets, large population centers, low-lying topography, and ports. Each grid can represent a part of the coast but does not extend into the open ocean. You can see examples of SLOSH predictions in the National Storm Surge Hazard Maps.

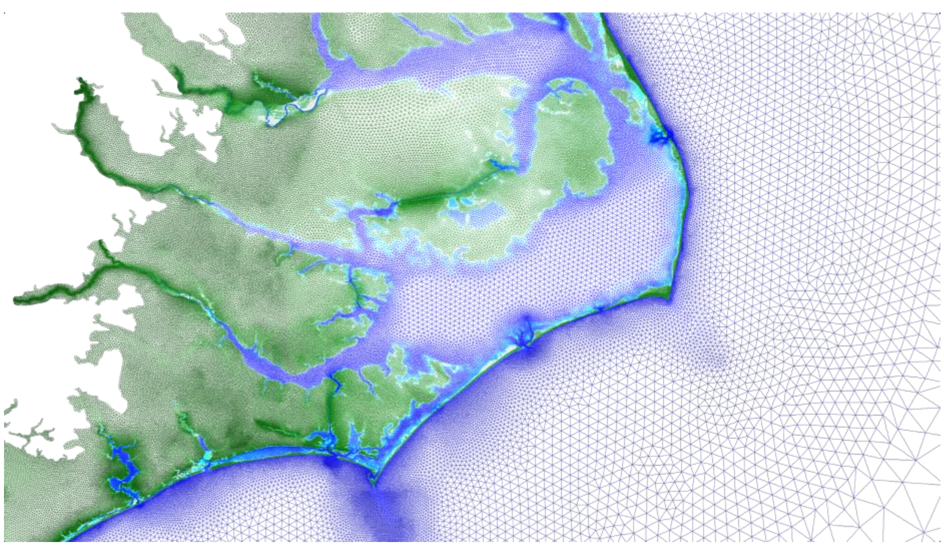

Figure 5: Close-up of ADCIRC mesh for North Carolina. Note how the triangular mesh cells can vary in size.

ADCIRC is a research model, and it is more complex and time-consuming than SLOSH. ADCIRC uses a better representation of the coast -- instead of a grid, it uses a mesh that is larger and highly-flexible. An ADCIRC mesh can have 10 to 100 times as much detail, and thus an ADCIRC simulation can be much more accurate in its prediction of storm surge and flooding. However, each ADCIRC simulation is slower and must be completed on a supercomputer in an hour or longer. It is common for ADCIRC to be used for hindcasts after storms, to help with design of levees by the U.S. Army Corps of Engineers and flood risk maps by FEMA. But it can also be used for forecasts via the ADCIRC Prediction System.

Differences between the SLOSH and ADCIRC models are mainly in the following three areas: mesh shape and resolution, the physics contained in the model, and the cost. A comparison between the SLOSH and ADCIRC storm surge models is given in the table below.

Table 1: Summary of differences between SLOSH and ADCIRC. Adapted from HurricaneScience.org.

	SLOSH	ADCIRC
Grid / Mesh	Grid, structured curvilinear, rectangular cells, resolution can change gradually	Mesh, unstructured, triangular cells, resolution can vary quickly
Physics	Two-dimensional, no ocean surface waves	Two- or three-dimensional, with ocean surface waves
Cost	Low, a few minutes on a laptop	High, an hour or longer on a supercomputer

It is hard to say which model is better, because parameters can be adjusted to give accurate predictions. Both SLOSH and ADCIRC are accurate within 20 percent given a perfect track, intensity, and size of the hurricane. If the model predicts a peak storm surge of 3 m (about 10 ft), then the observed/true peak is likely to be between 2.4 to 3.6 m (about 8 to 12 ft).

However, SLOSH can perform badly for some unusual hurricanes. For example, Hurricane Ike (2008) was so big that it caused storm surge and early flooding when the storm was far offshore, but SLOSH did not predict this flooding because its grid did not extend into the Gulf of Mexico. ADCIRC had a better prediction of the early and peak flooding. SLOSH is fast and accurate enough, but ADCIRC can be more accurate for a wider range of storms.

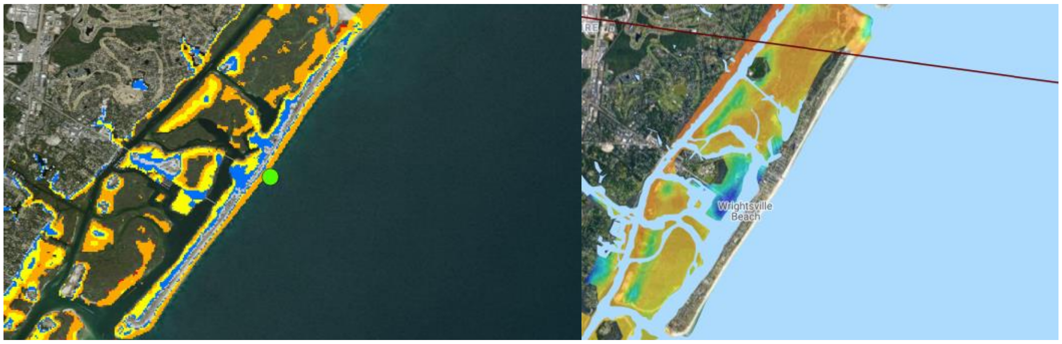

Figure 6: Comparison of SLOSH and ADCIRC predictions for coastal flooding during Hurricane Florence (2018) in Wrightsville Beach, North Carolina. Both predictions are for NHC advisory 56, which was issued about 24 hours before landfall. (Left) SLOSH predictions with orange colors to indicate depths of 6 to 9 ft above ground. (Right) ADCIRC predictions with orange colors to indicate depths of 6 to 8 ft above ground. SLOSH data from NHC Data in GIS Formats; ADCIRC data from Coastal Emergency Risks Assessment.

Discussion questions:

1. What does SLOSH stand for? What does ADCIRC?
2. What are the strengths and weaknesses of SLOSH and ADCIRC?
3. If a hurricane was approaching your home, then which model would you trust?

What are Typical Factors for North Carolina?

These computer models are accurate because they consider all of the factors that can influence the storm surge. But they are also costly -- we need a powerful computer to use them. It would be great if we had a simpler model.

We can build a simple model for storm surge by considering only: (1) wind speed, and (2) width and slope of the ocean bottom. We will over-simplify (and thus have a larger error!), but this simple model can still be useful. And its input factors are relatively easy to determine for a given storm.

For offshore geometry, we can use charts of the coastal ocean to determine the continental shelf width and the average depth. Nautical charts are provided by NOAA. These charts are used for navigation. The small numbers show the depths in feet, and the length scale can be used to measure distances.

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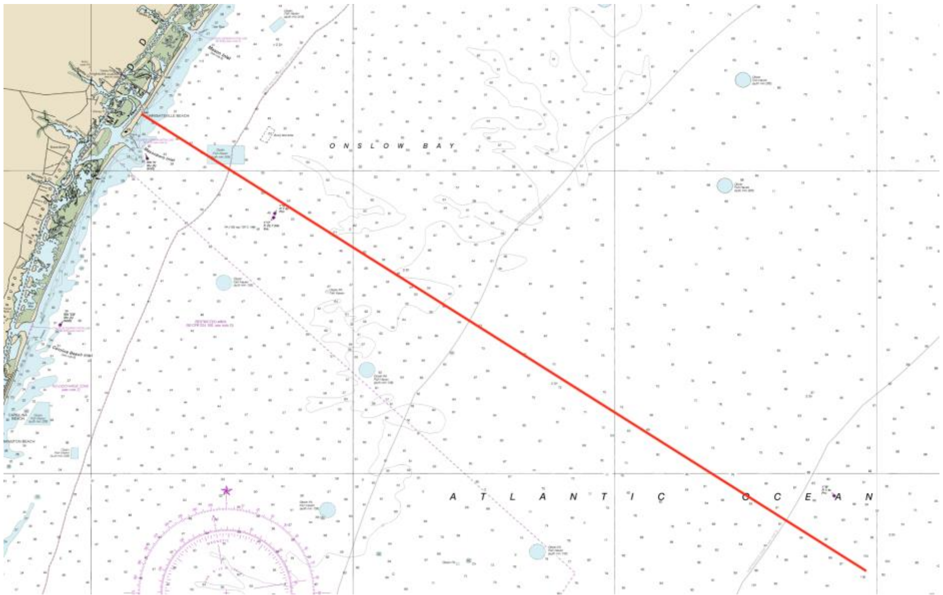

Figure 7: Example of using a NOAA nautical chart to find a shelf width near Wrightsville Beach, North Carolina. The red line extends from Wrightsville Beach to a depth of about 100 feet. Using the length scale at the bottom of the chart (not shown), we can estimate the length of this line to be about 27 nautical miles. Chart available from the NOAA Office of Coast Survey.

As an example, consider Hurricane Florence in 2018, which made landfall near Wrightsville Beach, North Carolina. Here is the nautical chart for that portion of the North Carolina coast. As shown in the figure above, we can measure a distance from Wrightsville Beach to a depth of about 100 feet, and we get a distance of about 27 nautical miles.

For wind speed, we can use the information about the storm at landfall. Hurricanes can be categorized via the Saffir-Simpson Hurricane Wind Scale, which ranges from minor hurricanes in Category 1 to major hurricanes in Category 5. A hurricane can be in several categories during its track. It will likely reach its highest category as it is strongest over the open ocean, and then it will drop to a lower category as it moves onshore.

Figure 8: Saffir-Simpson Hurricane Wind Scale.

For example, we know that Florence was a Category-1 hurricane as it made landfall. According to the hurricane wind scale, Florence's wind speeds were 74 to 95 miles per hour. We must pick one wind speed in this range -- let's assume its wind speeds were about 90 miles per hour, as it moved toward the coast.

Now we have the input factors for our simple model. For Florence in 2018, the storm made landfall near Wrightsville Beach, North Carolina. At that landall location, the shelf width was about **27 nautical miles**, the average depth was about **50 feet**, and the storm wind speeds were about **90 miles per hour**. We can use these input factors to predict the storm surge at Wrightsville Beach.

It is important to remember that these are only estimates. Even if we are careful in reading the nautical chart and the hurricane wind scale, our input factors will still have errors. And even if we knew the exact values for our input factors, there are many other factors that also influence storm surge. So our prediction will not be perfect.

Discussion questions:Pick a recent hurricane that affected the U.S. Don't pick Florence in 2018, but you can pick any other hurricane. Examples for North Carolina are Dorian in 2019, Matthew in 2016, Arthur in 2014, and Irene in 2011.

4. Where did the storm make landfall? Find a NOAA nautical chart for this location, and use it to determine an average depth and shelf width.
5. What was the storm's category at landfall? Use the hurricane wind scale to determine a wind speed for your storm.
6. What are the possible errors in the values you obtained?