The Dangers of Hurricanes and Storms Surges in Lewes, DE

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Every summer Lewes, Delaware attracts many tourists to the region. Most who visit do not worry about the threat of a hurricane to impact the region. Disaster planners must track tropical systems when they form over the Atlantic. If a system approaches the region storm surge models are called on to predict sea level rise. The coastline of Lewes plays an important role on the storm surge. All these variables are necessary to prepare evacuation orders should the time come.

Hurricane Models

With the recent devastation of Galveston, Texas by Hurricane Ike and the less recent catastrophe of Hurricane Katrina in New Orleans there is much concern about how prepared coastal areas are when it comes to a hurricane strike. It is important for city officials to know how hurricane severity is predicted and also how to determine when to evacuate.

In order to predict hurricane paths and intensity, weather forecasters and climatologist use models. Models are Mathematical equations that represent the physical laws governing the behavior of the atmosphere. The equations represent the extent to which atmospheric quantities such as temperature, humidity, wind speed and direction, etc. will change from their initial values at present time. Solutions to these equations are the prediction or forecast (1).

There are three main types of hurricane forecast models; statistical, dynamical, and combination models (2). Statistical models take the current meteorological conditions of a hurricane and compare them to historical storms. The benefit of statistical models is

that they are very fast and are considered to take "no skill". Dynamical models look at the entire global atmospheric condition and solve forecast equations at every point on the global grid to predict the future state of the storm. Dynamic models are the best forecasting models that exist for tropical cyclones. The problem is that these models take the most time to run and are computer intensive. Time is a major factor when predicting storm paths when they are close to landfall. Combination models are a hybrid of these two model types that take forecast data and put it into a statistical framework (1).
The meteorological parameters of a hurricane that are important are the intensity of the storm, the atmospheric pressure, the tract of the storm, the forward speed, and the radius of the maximum winds. All of these parameters will ultimately affect the size of the storm surge (2).

The major uncertainties in predicting hurricanes lie in the storm tract and the intensity of the storm when it makes landfall (2). This is why the surge was overestimated for Galveston, TX. The storm changed its path just before it made landfall (3).
The leading storm surge model, the SLOSH model, requires the storm tract, the central sea level pressure, and the maximum radius of winds divided into sea surface wind stress and pressure forces (4).

Storm Surge:

"From a surge-saturated building's perspective, each cubic yard of water breaking against it is like getting punched by a wrecking ball weighing nearly 1,700 pounds" (5).
A storm surge is the inundation of the ocean onto coastal areas that often accompanies a tropical system. It is one of the most dangerous aspects of a hurricane. Storm surge is similar to rainfall as it can cause significant flooding. The difference is that storm surge

can cause a much quicker rise in water level. Furthermore, storm surge is much harder to predict than flooding.

The main government used model for predicting storm surge is SLOSH. This model uses the predicted storm track and intensity given by hurricane models. It then attempts to calculate the rise in water level by starting with the elementary physics. For example, the inverted barometer effect can contribute several feet of storm surge due to the decrease in pressure of a tropical system (6). Also a drag force keeps the air from accelerating to unreasonable levels (500 knots). SLOSH's output is displayed by using a series of grids. Each grid point is a representation of a location in the ocean. All points are given a prediction of the storm surge irrespective of the tides. There are almost always less spacing between grid points near land (7). This helps to give a better a better forecast (more data points) while not taking up too many resources.

There are several major factors that contribute to the strength and danger posed by storm surge. One of the most predictable factors is the local tides. Tides lead to a natural rise and fall of water level. The tide differential in Lewes, Delaware is roughly four feet (8). This means that if the maximum storm surge hit Lewes during high tide, the water level would be roughly four feet higher then if it hit during low tide. The maximum wind speed correlates strongly with maximum storm surge. For example, for a Category 2 hurricane (winds 96-110 mph), the Saffir-Simpson scale predicts a surge of about 6-8 feet (9). The worst storm surge along the east coast is almost always experienced on the northeast quadrant of the tropical system and is close to the center of circulation. This is where the wind is typically blowing the water straight onto the coast. In addition, there is typically a

movement of the center of circulation of a tropical system onto the shore. This adds momentum to the wind and water that is flowing in that same direction.

One of the biggest sources of error comes from the shape of the coastline. Coasts that are cup shaped can collect and funnel excess water causing increased surge. Other areas may have barrier islands which can deflect the incoming water. Rivers further complicate this problem. The SLOSH model handles a river in a one dimensional system. In other words, the water fills up the river and can only go in one direction, up. However, after a river overflows its banks it can spread out in all directions. Under certain conditions, rivers can overflow their banks solely due to inflow from other rivers. Unfortunately, the SLOSH model does not take rainfall amounts into it's forecast (10).

Storm surge research is still in it's early stages. Currently, error rates are typically near 20% of total surge. A critical point for flooding in Lewes is a surge of around 8 feet at high tide. Therefore, a 6 foot surge prediction should arouse concern. Research is being done to look at the "lag time" between the maximum wind speed and the maximum storm surge (11). This is an important factor to consider for the Mid-Atlantic coast. Cold waters dominate the region to the East of the Gulf Stream. This can often lead to a storm weakening just before making landfall. Other research is looking into the potential of resonance of waves in the Gulf of Mexico (7). This could affect Lewes by means of the Delaware Bay.

Lewes' Coastline:

Within the last century multiple storms and hurricanes have hit directly on or near the Galveston coast (NOAA hurricane paths). These storms have brought intense winds and devastating storm surges. On September, 14 2008, hurricane Ike hit the Galveston

coast with a storm surge of about 10-12 feet. The prediction for the surge was over 25 feet in height (14). This scenario is much different that what we experience in Lewes. We have never experienced a storm surge of that magnitude, nor have we had one to be predicted to be that high. Lewes differs from Galveston because we have never been directly hit by a hurricane. They have passed to our East and West. Hurricanes have also hit to our South but were weakened to only tropical storms by the time they reached our vicinity (13).

Lewes has somewhat of an advantage that it is geographically sheltered from Atlantic storms but this does not mean that it is protected from flooding. Lewes's low-lying elevation makes it vulnerable to flooding. Nearly one-third of all real-estate plots would be flooded by a 100-year flood. Lewes can be inundated from the sea by two direct sources. Parts of the town located near the Delaware Bay can be flooded directly by storm surge and wave action. Lewes also has the disadvantage that the Lewes & Rehoboth Canal cuts through the town. Since the canal is driven by tides, it is prone to flooding its banks as the tide height increases due to storms (14).

Not only does Lewes have to worry about costal flooding, it has to worry about fresh water flooding from precipitation. When hurricanes hit to our south, they can attenuate into tropical storms. Tremendous amounts of precipitation are associated with weaker storms that move slowly through a region or even stall (16).

Lewes has a history of flooding from hurricanes, tropical storms and Nor'easters. In the last century, flood elevations of at least six feet have been recorded during eight different events. A majority of theses floods were due to Nor'easter storms (17).

Recommendations/Conclusion:

The good and the bad, here is what you need to know concerning evacuations of Lewes, DE. The odds of a hurricane making a direct hit near Lewes are especially low. In fact most of the tropical activity in the region follows two categories. The first involves a storm hitting near the Carolina's and then moving over Delaware when it is much weaker. This has the potential for significant flooding due to rainfall but not storm surge. The second common scenario involves a tropical system skirting the coast. This can bring minor surge and rainfall to the area but not on the scale of ordering evacuations.

What is exactly needed to order at least small scale evacuations of Lewes? This is a tricky and situation dependent question, but at a minimum, guidelines can be developed. As far as storm surge alone, we would recommend at least a small scale evacuation if conditions predicted an eight foot storm surge. A surge of this height could flood many beach front homes and include strong waves that might collapse older buildings. Obviously, the timing of the surge along with high tide would need to be looked at. Evacuations related to flooding would depend on the total rainfall, max rainfall rate, and span of significant rainfall. Depending on these factors, we would recommend considering evacuation if the total rainfall reaches eight inches over a wide swath of Delaware. A combination of six foot surge and six inches of rain may call for an evacuation of some areas. Areas of evacuation would be the outskirts of Lewes on both sides.

While not mentioned previously, there is the potential for a major hurricane to hit Lewes head on. Inferring from historical data, we would put the odds of this somewhere in the range of 1 in 1000 in any given year for a storm of Category 2 or above. This is a very rough range just to bring in some perspective. Hurricane Isabel was somewhat of a

scare earlier on. It came from a very peculiar track where it could have hit Delaware. Instead it hit a several hundred miles to the south. The maximum storm surge in Lewes has been about 8-9 feet (8). Therefore we project a maximum storm surge of a Category 2 hurricane to be around 10-12 feet. This would require a major evacuation of the Lewes and surrounding areas. Fortunately, tropical systems rarely form close to Delaware. This provides us with a several day buffer to contemplate and initiate evacuation orders. Hurricane Isabel drifted over the Atlantic Ocean for well over a week.

Pre-project Thoughts:

In the beginning of the project our group was very lost. Well to be honest throughout much of the project we were very lost. Our inclination that water and storm surge was the most important variable to consider when advising whether or not to evacuate ended up being quite accurate. In the begging it seemed as though it was just a shot in the dark. By searching the internet in a very broad sense it helped us to figure out some more information about hurricanes. It also overwhelmed us with the amount of information that was available. It also felt as though we had even gone a step backwards.

For the presentations we decided that the best thing to do was to split up the work. We each had to research a different topic because the amount of info was too over whelming for one person to handle. A general Google search was a good way to start out but to really dig into the information, finding published scientific articles was the way to go. This is because we needed to gear our presentation more for an educated audience that really wanted to learn something new. It was hard to find a lot of published science articles that were related to Lewes. Since hurricanes do not directly hit our town it was hard to find articles about it.

In order to find the hurricane model information, I first did a very general search on the web. This was due to the fact that I knew nothing about forecast models before going into this project. It was very difficult for me to know what to look for since a lot of the buzz words associated with meteorology was new to me.

When focusing on the presentation, I was not sure what to hone in on because there was a lot of information available to me that all seemed relevant. I had little to no filter on the wealth of information I was finding. When we came across the SLOSH model and information about the dangers of storm surge, we knew that was what we should focus on. I decided it would be good to introduce the basics behind hurricane prediction anyway, and use it as a means of introducing storm surge and ultimately the SLOSH model.

After Project thoughts:

This project was certainly different and a new style of learning. It seemed as though this project was more about learning how to search the internet and making a presentation to the public than it was about actually learning Physical Oceanography. A lot of the confusion we had as a group was trying to figure out exactly where you wanted the goal of the project to end up.

As unconventional as this project seemed to me in the beginning, I learned a great deal in a short amount of time and the subject matter was very interesting. It became obvious to me that I need a lot more practice approaching broad problems such as the one assigned. Learning what information people find relevant and what is old news was a very important skill to realize. This fits in with the concept of knowing the audience that

you are trying to present to. I could not help thinking the woman from the city council had to be very bored at some points during our talks.

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