Coastal Inundation due to Storm Surge as Sea Level Changes along the Northern South Carolina and Southern North Carolina Coast

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Abstract

This study made use of the storm surge model in Peng, Xie, and Pietrafesa (2004) and Xia et al. (2004), to predict coastal inundation along northern South Carolina and southern North Carolina as sea level rises. Hurricane Hazel (1954) was used as the reference hurricane in this study, which made landfall at 33.85°N, 78.57°W, as a category 4 hurricane. Data was plotted and analyzed using Matlab, to produce inundation maps for four sea level rises (0.2m, 0.6m, 1.0m, and 2.0m). The greatest net storm surge was produced during a 2m sea level rise, which in return caused the greatest amount of inundation. However, inundations caused by different sea level rises were not drastically different. It is hypothesized that the minor difference between sea level rise and the resulting inundation is due to the inland topography of South Carolina and North Carolina. The greatest inundation for all four sea level rises occurred along the shores of Winyah Bay and Hogs Inlet, SC and Oak Island, NC. The results for this study may be used to implement hurricane evacuation plans, building restrictions, city plans (such as drainage, beach nourishment, etc.), and other community decisions.

Introduction

Tropical cyclones are significant weather phenomena that impact the southeast United States. Extreme winds, heavy rainfall, and elevated sea levels (storm surge) produced by the storm can cause major threats to the coast. Storm surge, which causes sea level coastal flooding, is produced by strong winds and low atmospheric pressure over an area. Storm surge is dependent on numerous factors; three of which are the tidal cycle at the time of the surge, the topography over which the surge intrudes, and the strength of the low pressure system in the atmosphere (Figure 1). Sea level rise can cause storm surge to amplify, causing detrimental effects on coastal communities. The risk of storm surge as sea level rises must be quantified for coastal communities for applications such as the following: standards for buildings and coastal infrastructure, the location of building developments, emergency management, and indirectly for tourism (McInnes et al., 2001).

This study examines the impacts of sea level rise on the storm surge produced by a tropical cyclone, for the Grand Strand, South Carolina and southern coast of North Carolina. Myrtle Beach, South Carolina has topographic features similar to ridges, that elevate certain areas inland of the coastline (Figure 5). Higher elevations limit the progression of storm surge; therefore, areas with low topography will be largely affected by storm surge. Due to low elevations, areas such as salt marshes, inlets (Murrells Inlet, SC and Hogs Inlet, SC), and bays (Winyah Bay, SC), will experience the largest effect from increased storm surge. As sea level increases, the storm surge may affect the Myrtle Beach area significantly more, because areas that generally do not experience storm surge, due to their elevation, might be impacted by such events.
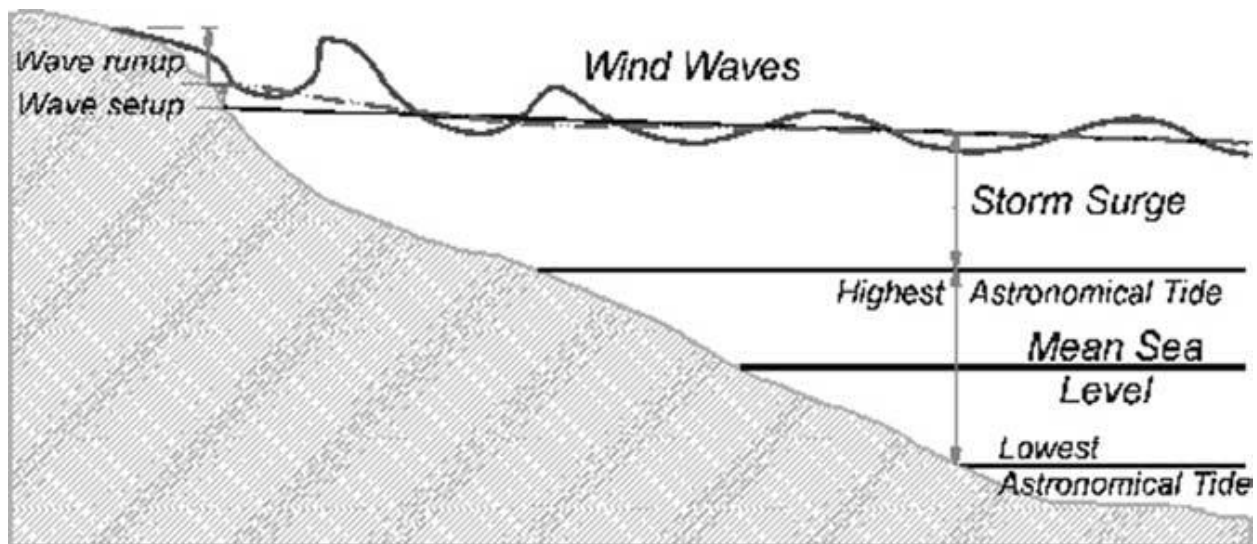

Figure 1. Contributions of Storm Surge on the Coast (McInnes et al., 2001)

Sea Level

The current global trend in sea level shows an average rise, due to melting glacial ice. Some projections estimate that sea level will rise between 0.5-2 meters by the year 2100 (Titus 1989). During the twentieth century, tidal gauges recorded the global sea level rise to be 1.7-1.8 mm/a (Douglas 1991) larger than the rate from the late Holocene (Shennan and Horton, 2002).

Changes in sea level vary with each location, and are largely dependent on seafloor topography. As of 1999, the global average sea level rise is approximately 8 inches per 100 years; however, along the South Carolina coast, Charleston Harbor in Charleston, SC experienced a rate of 1.08 feet per 100 years, and Springmaid Pier in Myrtle Beach, SC had a rate of 1.7 feet per 100 years (Davis 2007). The measured sea level rise in North Carolina, as observed by a study conducted between Tump Point and Sand Point, was 3.0-3.3 mm/a, during the twentieth century. This value included a background rate of approximately 1 mm/a, with an abrupt increase in sea level of 2.2 mm/a, which started between 1879 and 1915 A.D. The acceleration observed at the North Carolina coast was larger than other studies conducted further north along the United States and Canadian Atlantic coastline, and is hypothesized to be indicative of latitudinal differences (Kemp et al., 2009).

Increased sea levels are potentially crippling to coastal towns, as inundation will significantly alter the landscape. However, potentially even more dangerous is that increased sea levels will affect the net storm surge produced by tropical cyclones. Sea level rise will amplify storm surge in certain areas, causing massive amounts of coastal flooding.

South Carolina Coast

The South Carolina coastline extends approximately 187 miles, and seven counties border the Atlantic Ocean which are susceptible to sea level rise and storm surge. Of the coastline, 909 square miles are less than 5 feet above sea level (Figure 5), increasing the threat of storm surge. Nearly a quarter of the state's population, approximately 930,000 people, reside within the seven coastal
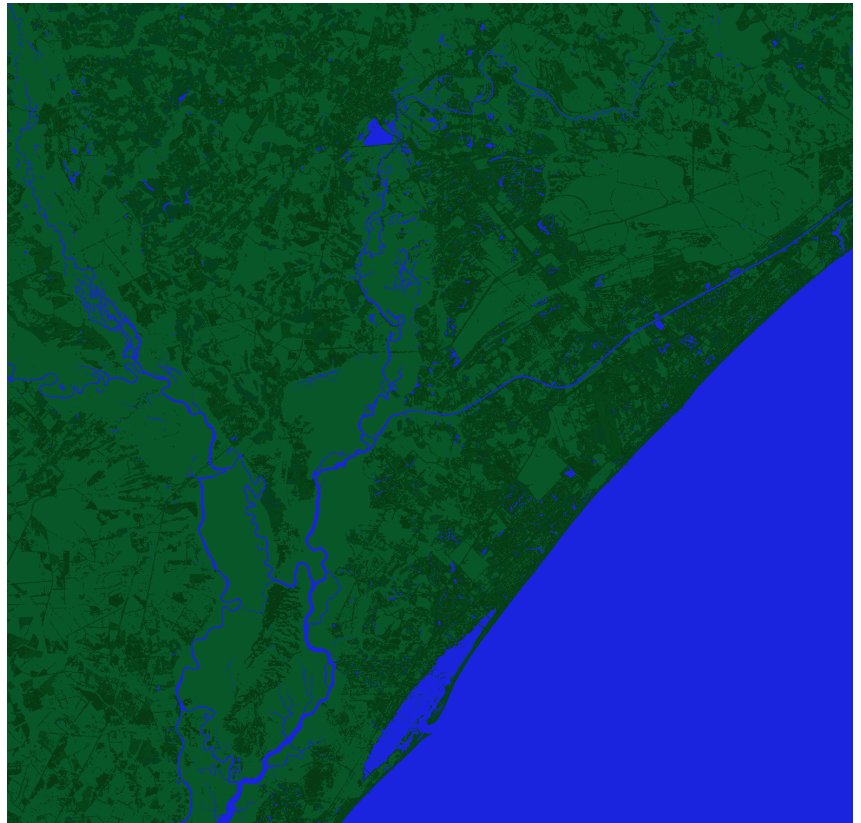

Figure 2. Watersheds Throughout Northeastern Coastal South Carolina

counties; four of which are currently in the top ten fastest growing counties in the state: Beaufort, Horry, Georgetown, and Charleston (Census 2010).

Water sources present in the Grand Strand, South Carolina region are shown in Figure 2. The data was obtained from Landsat and was manipulated using MultiSpec. The swath and section of the data is p015r037_7x20000511, and is displayed in three wavelength bands: blue, light green, and dark green. All water in the figure is represented by blue, undeveloped regions in the area are represented by a lighter green, and human developed areas are represented by dark green. Areas surrounded by blue (water), are highly vulnerable to storm surge. Therefore, low lying regions near coastal water bodies are significantly impacted by a cyclone's storm surge. There is also a high concentration of dark green (developed regions), near the coastline. Areas near the coast are extremely susceptible to storm surge. Higher the concentration of human development near the coast, the greater the impact major storms, and their induced flooding, will have on coastal communities (Figure 2).

Hurricane Hazel

On October 5, 1954 a tropical storm, Hazel, was located approximately 50 miles east of Grenada. October 12, a low pressure system formed in the upper atmosphere above the central Caribbean. The low pressure gradually turned Hazel northeastward over Haiti, making landfall as a category 4 hurricane with sustained winds of 139 mph. October 13, a second upper level trough of low pressure formed over the Mississippi Valley, United States, and caused Hazel to move across the southeastern Bahamas. Following landfall over Haiti and the Bahamas, Hazel strengthened, achieving sustained winds of 150 mph and traveling between 30-50 mph.

At 1100 EDT on October 15, Hurricane Hazel made landfall near the South Carolina/North Carolina border (33.85°N, 78.57°W) as a category 4 hurricane. Hazel made landfall with a barometric pressure of 937 millibars, producing a storm surge up to 18 feet, at Calabash and Holden Beach, North Carolina. Everywhere between Southport to Topsail Beach, NC, the storm surge was larger than 15 feet. The initial landfall of Hazel coincided with high tide during an October full moon, which was the highest lunar tide of the year; amplifying the storm surge of the tropical cyclone. The water level on the Cape Fear River reached the highest level ever known (Ludlum, 2004).
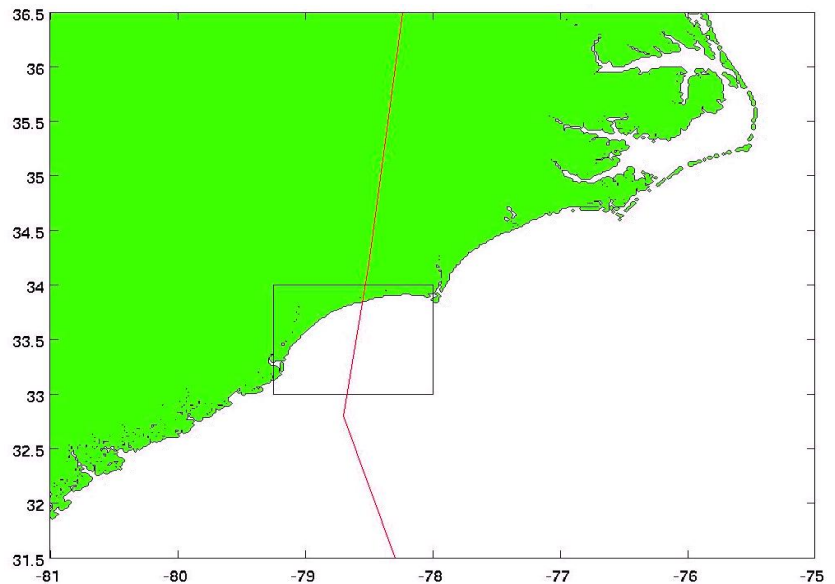
Multiple waterways

Figure 3. Path and Landfall of Hurricane Hazel at the North/South Carolina Boarder on October 15, 1954

interlace the terrain of northeastern South Carolina and southeastern North Carolina, such as the Waccamaw River and the Intercoastal Waterway. Storm surge is especially detrimental to riverine environments as sewage can be input into the river, which can result in a decrease in dissolved oxygen concentrations. Dissolved oxygen is vital for biological activity in a river, as dissolved oxygen uptake by organisms is used to produce energy through respiration. Therefore decreased oxygen, and even extremely low concentrations such a hypoxia, can hinder the development of life in a water body, causing the water to become inhabitable (Mallin et al., 1999).

During landfall, wind speeds between Myrtle Beach, SC and Cape Fear, NC ranged from 125-150 mph. High wind speeds in conjuncture with storm surge and rainfall totals, devastated coastal communities in Horry County, SC, and Brunswick County and New Hanover County, NC. At Holden Beach, storm surge destroyed all but 12 houses out of 300 located near the coast. In South Carolina, damage from Pawley's Island to Cherry Grove was estimated at 24 million dollars. In Myrtle Beach, SC homes were destroyed near the coast, which represented approximately 80% of the total houses on the waterfront. The damage reported in North Carolina was approximately $136 million in property damage; with 15,000 homes and structures completely destroyed, and 39,000 significantly damaged. The largest amount of damage occurred at the coast of Brunswick County, NC, over which the eye directly passed. For one area, the largest amount of damage occurred at New Hanover Beach, NC, estimating 17 million dollars worth; which included 362 buildings completely destroyed and 288 with major damage. All together, the total damage produced by Hurricane Hazel in South and North Carolina was estimated at $230 million, 1,635 houses destroyed and 16,655 damaged (Ludlum 2004).

A previous study, performed by the EDF, found that over the past 35 years, the potential for destruction and the intensity of tropical storms and hurricanes has doubled. The increase in storms and their intensity are expected to enhance as global warming continues to be an issue. The data the EDF used to generate storm surge maps for South Carolina were obtained from the South Carolina Hazards research lab project on coastal vulnerability. The EDF constructed storm surge maps to show how increasing hurricane intensity can increase the risk of flooding in the Myrtle Beach area (Figure 6). The EDF's study was extremely generic in that the resulting storm surge was not indicative of a specific storm; instead the storm surge was independent of landfall location and direction, storm speed, and other variables. The extent of the flooding shown on these maps illustrates the worst-case scenario, generated by the Sea, Lake and Overland Surges from Hurricanes (SLOSH) computer models. The data is compiled from hundreds of hypothetical hurricanes models simulated for various storm categories, storm speeds, landfall direction, and landfall locations, and used to construct the storm surge maps (EDF).

The EDF's study differs from this study, due to the observations of storm surge for a certain storm, Hurricane Hazel. According to the EDF study, the progression of the storm surge inland was not significantly different between a Category 2, 3, and 4 hurricane (Figure 6). The

Waccamaw basin and the shoreline south of Highway 501 experienced the greatest progression of storm surge inland as the strength of the hurricane increased (EDF).

Methods

The parameters of Hurricane Hazel from 1954 were used for this study. The area over which coastal inundation was studied is outlined by the rectangular box in Figure 3; 33°-34° N and 78°-79.5° W. Topography and bathymetry maps of the region were constructed using GEODAS Grid Translator, of NOAA's National Geophysical Data Center and coastal topography was also obtained through the use of Landsat. A three-dimensional storm surge model was used to simulate hurricane induced water levels and inundation of the Grand Strand area (Figure 3), similar to earlier work of Pietrafesa et al. (1997), Peng, Xie, and Pietrafesa (2004), and Xia et al. (2008), which used a series of numerical models to simulate storm surge on coastal regions.

This study used the storm-surge model in Peng, Xie, and Pietrafesa (2004) and Xia et al. (2004). The model is based on the hydrodynamics of the Princeton Ocean Model (Mellor, 1996), in which water column depth is used to scale the vertical coordinate. The horizontal grid uses an "Arakawa C" and orthogonal coordinates which are curvilinear. A three-dimensional model was used compared to a vertically integrated model because water levels and currents were underestimated in the vertically integrated model (Pietrafesa et al., 1986). The model uses a long time step based on the Caurant-Friedrichs-Lewy (CFL) condition, the external gravity waves, and complete thermodynamics of the system.

The inundation scheme used for this project is described in Xie, Pietrafesa, and Peng (2004) and Peng, Xie, and Pietrafesa (2004). The surface current was used as the inundation speed parameter. For water level in the vertical direction, three sigma levels and the horizontal resolution in the x and y direction, were determined for each 15 minute grid cell. Inundation of an area was determined by the water level of a grid cell adjacent to the coastline and comparing it to the land elevation next to it. If the water level was greater than the adjacent land elevation, then a second criterion was examined. The progression of water inland was determined through the time-step integral of the surface inundation speed at each grid point. If the water level travels over the corresponding grid size in either the x or y, or both directions, then the grid point will be flooded, or turned into a water point. If no water progressed over the grid point in the x or y direction, then the point on the grid will remained above the water level, and will not be altered due to storm surge (Xia et al., 2008).

Sea level anomalies produced due to the cyclone, during the time of landfall, were observed; plots of the anomalies were constructed using Matlab. The storm surge produced by Hazel for two different barometric pressures was observed for Hazel, 930mb and 940mb. The amplitude of the storm surge was observed over 25 hours with a time step of 50 seconds. The storm surge produced over a 24 hour period was constructed for each of the sea level rise scenarios, through the use of Matlab.

Matlab was used to compile the storm surge data obtained from the model and the corresponding location based on GEODAS. There were two reference maps used, which acted as a control to compare the results (Figure 4). Figure 4 (left), was used as the current sea level for the South Carolina coast, as of October 2010. This figure represents no coastal inundation, and is considered the sea level at which sea height anomalies will be compared. The figure to right represents the storm surge produced by Hurricane Hazel for the current sea level. The path and storm surge from Hurricane Hazel in 1954 were implemented on the current sea level to produce the storm surge in Figure 4. The resulting inundation produced by differing sea levels was compared to Figure 4. Each inundation map was compared by locating areas submerged under water and comparing those areas to the same location on the control map, and determining if the area is submerged.
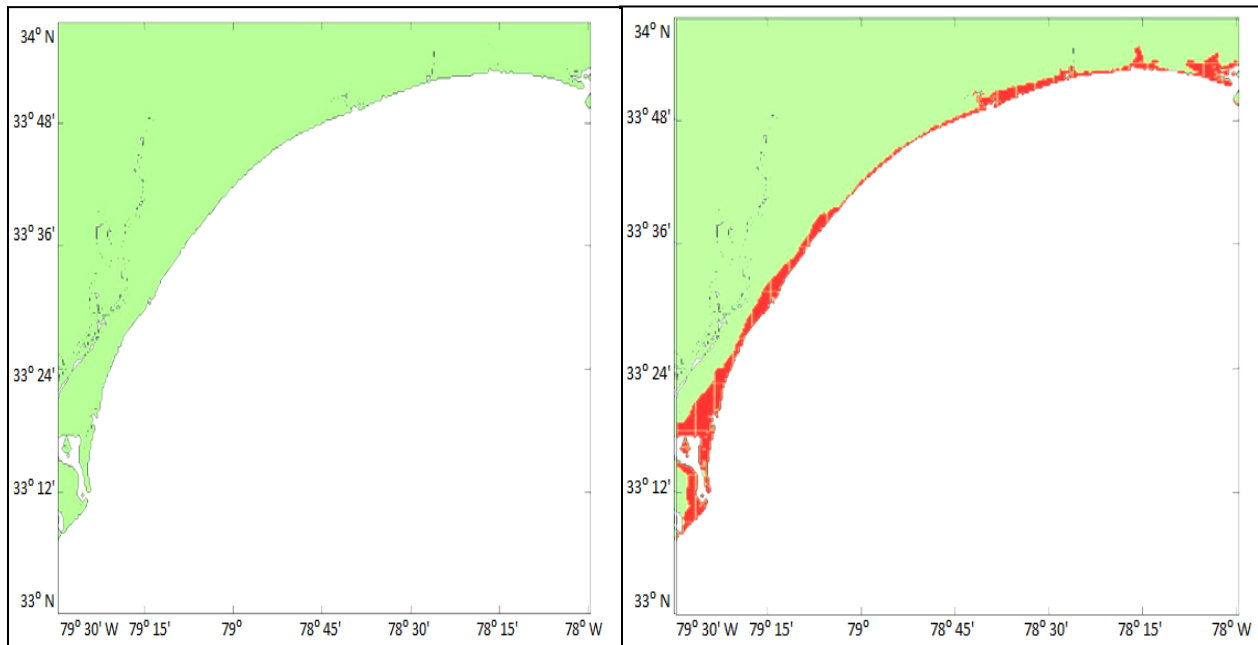

Figure 4. Sea Level (Left) and Coastal Inundation (Right) Reference Maps, for the Grand Strand, South Carolina. Areas of green are areas not affected by storm surge or sea level rise and remain instead remain dry. Areas covered by red are areas covered by water due to storm surge, which were previously dry land.

Four relative sea level rises were observed in this experiment: 0.2m, 0.6m, 1.0m, and 2.0m. The path of the hurricane and the factors which produce and influence a storm surge were held constant, such as wind and barometric pressure; only allowing the progression of the inundation to rely on the sea level height. The inundation caused by each sea level change was plotted using Matlab; each was then compared to the control sea level map (Figure 4). After inundation was determined for each sea level rise, the storm surge due to Hazel was implemented in the model. Inundation maps which included sea level rise and storm surge were produced in Matlab, and were constructed for each of the four sea level rises. Each map was compared to the control (Figure 4) to determine areas submerged under water for the experimental map, compared to if that area is submerged in the control map.

Results

        Hurricane Hazel made landfall at 33.85°N, 78.57°W, with a barometric pressure between 930 and 940mb. To observe the storm surge produced by Hurricane Hazel at present sea level, this study examined the hurricane at two separate pressures, 930mb and 940mb. The greatest storm surge, slightly larger than 6m, was produced with a pressure of 930mb; with a pressure of 940mb, the maximum storm surge produced was approximately 5.8m. The greatest storm surge was induced during landfall, and as the hurricane eye approached land, the storm surge increased exponentially (Figure 7).

        Sea level anomalies were plotted for Hurricane Hazel at landfall with a barometric pressure of 930mb (Figure 9). The plotted area encompasses 33°36'-34°N and 78°-78°30'W, where the dark blue in the upper left-hand corner represents land. The multicolored spectrum represents different sea level anomalies, with red being the greatest anomaly and blue being the least. During landfall sea level anomalies were greatest, about 6m, near the shoreline and extended approximately 20km down the shore. The further toward the open ocean, the smaller the storm surge, and at approximately 45km toward the ocean there was no net storm surge. Most areas in the plotted region experienced a storm surge near 5m during landfall (Figure 9). Storm surges produced over the region were later used to determine coastal inundation during landfall of Hurricane Hazel.

        However as sea level rose, the net storm surge produced also increased. Figure 8 represents the net storm surge produced by Hurricane Hazel with a barometric pressure of 940mb, as sea levels rises. The net storm surge was determined by calculating expected water heights due to storm surge and comparing them to a base sea level, which for this study was the present day sea level as of September 2010. For example the storm surge due to a 1m sea level rise is equal to the storm surge produced by the hurricane at a 1 meter sea level rise plus the additional amount sea level rose compared to the base sea level, so 1m for this example. Four different sea level rises were observed (0.2 m, 0.6 m, 1.0 m, and 2.0 m) and the resulting storm surge was calculated. The maximum storm surge with a 0.2m sea level rise was approximately 6.1m. A 0.6m sea level rise induced a storm surge near 6.4m, a 1m rise produced a storm surge of 6.8m, and a 2m rise caused a storm surge of approximately 7.3m (Figure 8).

        A sea level rise of 0.2m caused very little additional inundation. The greatest inundation occurred near Winyah Bay, and the extent of the inundation was extremely limited (Figure 10). The resulting inundation caused by Hurricane Hazel's storm surge with a 0.2m sea level rise was not significantly different from the inundation that Hurricane Hazel would have produced at the current sea level (Figure 4; Figure 10). The greatest inundation occurred near Winyah Bay, with a majority of the area flooded by the storm surge. Areas toward North Myrtle Beach and Hogs Inlet also experienced massive amounts of coastal flooding due to the storm surge. The least amount of inundation occurred near 33°40'N, 79°W. Inundation at the previous location was extremely limited inland, and resulted in little coastal flooding (Figure 10).

        A 0.6m and 1.0m sea level rise displayed similar inundation results, for both inundation due to a sea level rise and inundation due to a sea level rise and storm surge (Figure 12; Figure

13). A sea level rise of 0.6m and 1.0m caused increased inundation compared to a 0.2m sea level rise; however, the inundation is not significantly larger. Winyah Bay experienced increased inundation and further flooding started to occur near North Myrtle Beach (Figure 12; Figure 13). For a sea level rise of 1m, inundation began to occur all throughout the grand strand region; most notably inundation began to occur near the city of Myrtle Beach, where coastal elevations are higher than other surrounding coastal communities (Figure 13). The inundations caused by Hazel's storm surge and a 0.6 and 1m sea level rise, are comparable to the inundation caused by Hazel's storm surge at the present sea level (Figure 4; Figure 11; Figure 12).

The largest inundation occurred with a 2m sea level rise. Various areas of the land surrounding Winyah Bay are completely submerged, along with areas surrounding the Waccamaw River and Intercoastal Waterway. The extent of inundation inland around the city of Myrtle Beach is still limited; however flooding is more widespread compared to the other three sea level rises observed. Inundation caused by Hazel's storm surge is greatest for a 2m sea level rise. All areas around Winyah Bay are completely submerged and the water has progressed further inland. Some areas near the coast are completely flooded past the Intercoastal Waterway, and significant flooding is even observed in the city of Myrtle Beach (Figure 13).

Discussion

The purpose of this study was to predict coastal inundation by a major hurricane, Hurricane Hazel, as sea level rises along the South Carolina coast. Hurricane Hazel was a category 4 hurricane when it made landfall near the South/North Carolina border, having a barometric pressure between 930 and 940mb. It has been widely suggested that as the pressure of a hurricane increases, the resulting storm surge increases (Nicolle et al., 2009). The results for this study support the previous statement, because the storm surge produced by Hurricane Hazel was greater at a pressure of 930mb compared to 940mb (Figure 7). The difference in storm surge of Hurricane Hazel at 930 and 940mb was approximately 0.6m. This is a significant difference because a 0.6m rise in seawater can cause a large amount of coastal inundation. Differences in storm surge can also be observed in previous studies (EDF); as the barometric pressure in the cyclone decreases, the storm intensifies and can be upgraded to a higher category. Higher category hurricanes produce stronger storm surges; therefore a category 4 hurricane will produce larger coastal inundation compared to a category 2 or 3 hurricane (EDF).

There has been an overall global increase in sea level heights over the past century. Higher sea levels have the potential to amplify storm surge, causing inundation to occur further inland than average. This study found that as sea level increases, the net storm surge produced will be greater, causing greater amounts of coastal flooding due to storm surge. The greatest storm surge occurred during a 2m rise to the present sea level. Surprisingly the net storm surge produced for a 2m sea level rise was not equal to the storm surge produced by Hazel at the present sea level plus 2m, and instead was smaller, approximately 7.3m. This may imply that if sea levels exceed a certain height, then the resultant storm surge may be limited. This may be due to the fact that increased sea levels will cause the cyclone to travel over shallower water for

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an extended time period. Hurricanes receive energy from the underlying water, and if water depths are too shallow, then formation can be inhibited. Therefore, if sea level rises and causes the hurricane to travel over shallow water for a longer distance, the hurricane may weaken causing a reduced storm surge.

The largest storm surge produced by the cyclone was in close proximity to North Myrtle Beach, near the location where the storm made landfall. Storm surge, caused sea levels to reach a maximum height around 6m above current sea level (Figure 9). Storm surge predictions for this study coincided with previous collected data which studied the storm surge of Hurricane Hazel in 1954 (Ludlum, 2004). This suggests the model used in this study has validity, since the storm surge predictions coincided with previous reports and studies. It may be expected that regions which experience the greatest storm surge, will also experience the greatest flooding. The previous assumption can be observed by comparing the cities of Myrtle Beach and North Myrtle Beach. Both cities have similar topography (Figure 5); however, North Myrtle Beach received a greater storm surge due to Hazel (Figure 9). Due to an elevated storm surge, inundation was significantly larger in North Myrtle Beach than in Myrtle Beach (Figure 4). However, areas surrounding Winyah Bay experienced the greatest inundation, and not regions near landfall.

This suggests that other factor other than storm surge impact the inundation that will occur on a coastline. One factor that may alter the extent of inundation is the topography of the coastline. Areas around Winyah Bay, the southern part of the Grand Strand, and the Waccamaw River Basin are barely above sea level (Figure 5). Therefore these regions are more susceptible to sea level rise and storm surge because coastal flooding will progress further inland. Even though the storm surge was greatest near North Myrtle Beach, areas near Winyah Bay experienced the greatest flooding, due to low elevations (Figure 4).

Due to a net storm surge of approximately 7.3m, inundation was greatest during a 2.0m sea level rise compared to a 0.2m, 0.6m, and 1.0m sea level rise (Figure 8). Low elevation areas were the most affected by sea level rise, especially those near Winyah Bay. Winyah Bay filters two rivers, which are surrounded by low-lying elevations (Figure 2). A 2m sea level rise flooded parts of river basin. This suggests that as sea level rises, low lying elevations, on the coast and inland, will experience permanent flooding. However, not only did a rise in sea level cause increased coastal flooding, but the net storm surge due to Hazel increased as sea level increased.

Overall there was not a drastic difference in coastal inundation due to Hazel's storm surge as sea level rose. Limitations of storm surge progressing further than it did, may be due to South Carolina's topography inland from the coast. A majority of the Grand Strand, inland of 15km, has an elevation greater than or equal to 8m (Figure 5). The highest observed storm surge in this study was just over 7m; therefore areas higher than 8m will not experience flooding. This is significant for Myrtle Beach because coastal attractions and tourism account for 40% of the city's total revenue (Census 2010). Therefore the implications of increased inundation from a storm surge due to sea level rise are of high interest to cities such as Myrtle Beach.

According to the results, almost every coastal town/city in the Grand Strand region experienced flooding due to Hazel's storm surge. Major inundation occurred near Winyah Bay, submerging the majority of: the city of Georgetown, Pawley's Island, Murrells Inlet, Garden City, and Surfside Beach, South Carolina along with Southport, Oak Island, Holden Beach and Sunset Beach, North Carolina. All of the previous cities are extremely susceptible to a hurricane's storm surge, because the elevation of these regions is between 0-5m above sea level (Figure 5). Coastal development of the studied area has drastically increased since 1954; therefore property damages and losses would be significantly higher than they were for Hurricane Hazel (Ludlum, 2004). Coastal flooding may devastate communities, impact the economy, and cause detrimental effects to tourism. The predicted inundation from storm surge as sea level rises might be used to aid in evacuation zones, hurricane planning, housing construction, and other environmental planning concerning hurricanes.

This study found comparable results to the storm surge predictions by the EDF. The scope for the EDF study was broad compared to this study, as the predicted storm surge for the EDF study was independent of the hurricanes forward speed and path. Due to a narrower scope, this study provided greater resolution. For example, where Hazel made landfall, greater inundation is witnessed in this study compared to the study by the EDF. An explanation for this may be due to increased storm surge where the hurricane made landfall, causing increased inundation. Compared to the EDF study, results for this experiment found that expected storm surge inundation, due to sea level rise will progress further inland than originally expected.

Expansion of this study may be used to determine coastal inundation beyond 2m. Widening the study range will also allow more areas to be examined, providing possible inundation maps for the whole eastern United States' coastline. Another possible expansion of this study would be to allow more variability of the hurricane such as: strength, path, forward velocities, etc. This would allow predictions for a wide range of hurricanes, and provide coastal cities scenarios for which they might prepare for.

Conclusion

As sea level rises, the net storm surge produced by a hurricane increased. However along the northern South Carolina and southern North Carolina coast, the inundation was not drastically different between a hurricane with a 0.2m sea level rise and the same hurricane with a 2m rise in sea level. Inundation was likely limited due to the topography of those regions; areas inland from the coastline have an approximate elevation greater than or equal to 8m, larger than the net storm surge produced by the experimental hurricane (Hazel). Areas surrounding Winyah Bay, Hogs Inlet, and Oak Island experienced the greatest inundation, and were submerged under water for all of the predicted storm surge models.
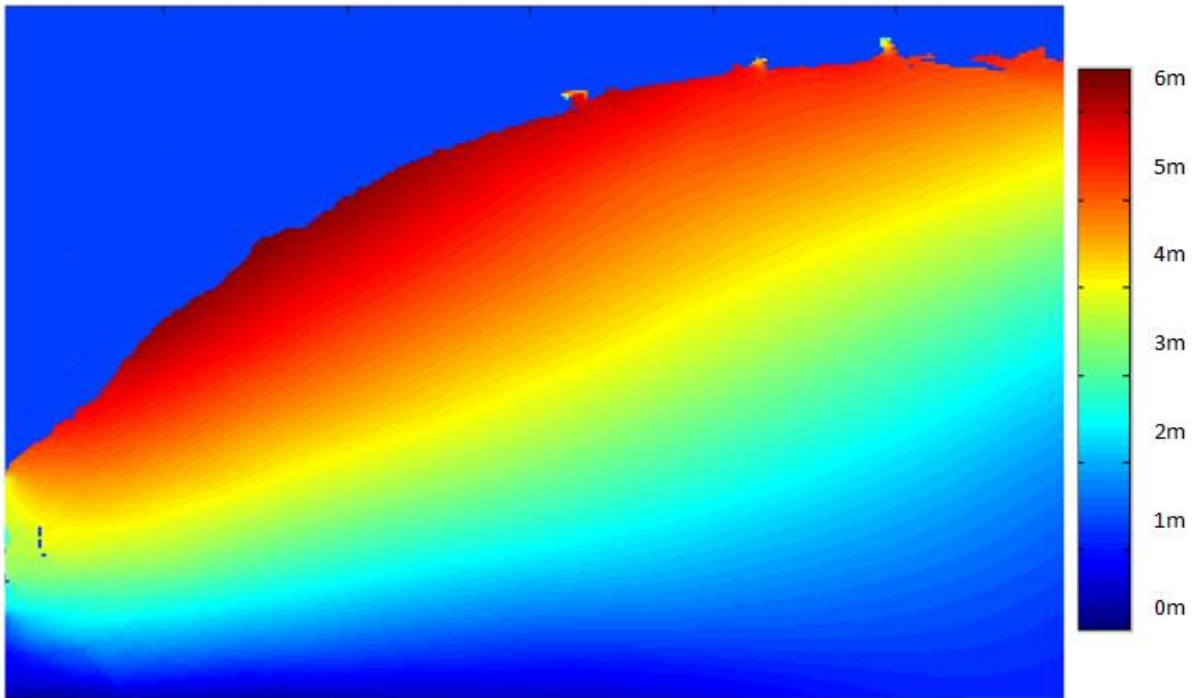
Figure 9. Sea Level Anomalies during Landfall at 33.85°N, 78.57°W due to Hurricane Hazel with a Pressure of 930mb
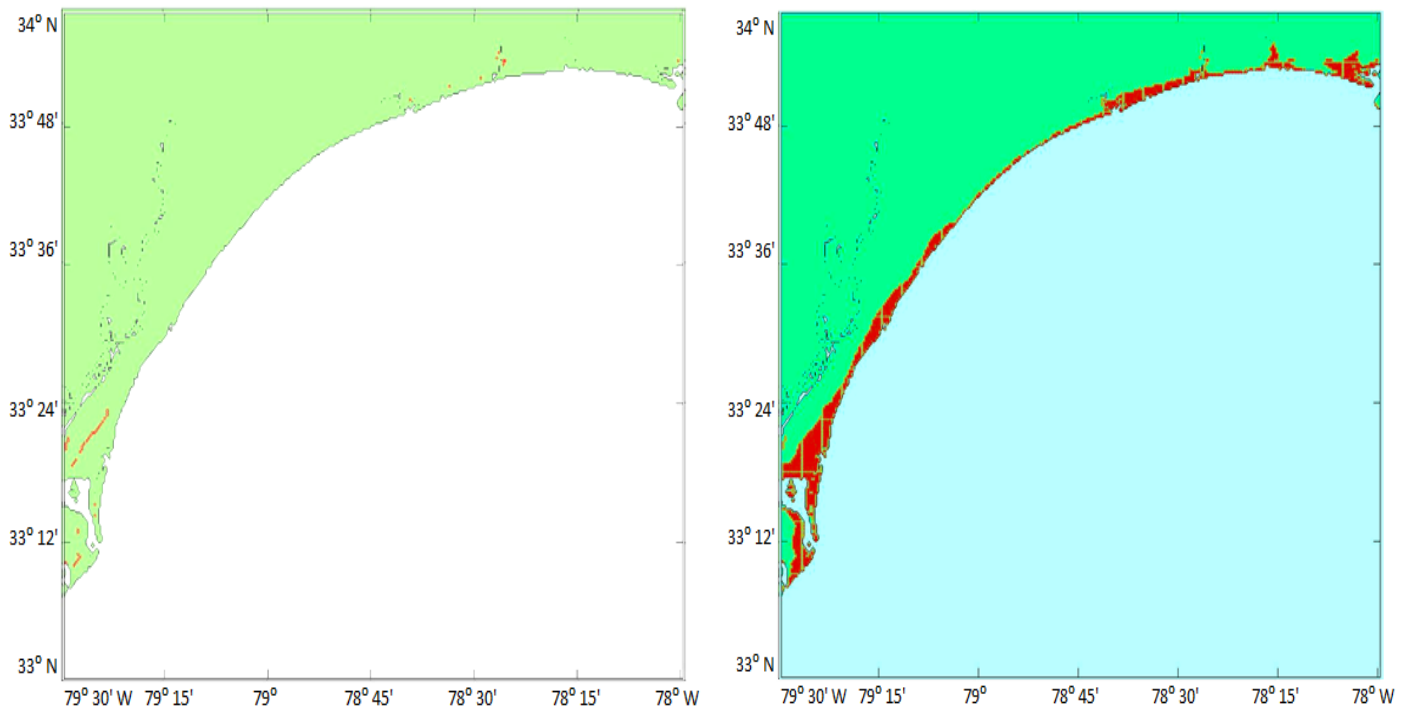

Figure 10. Coastal Inundation due to a 0.2m Rise in Sea Level, Along the South and North Carolina Coast. Inundation due to a 0.2m sea level rise, compared to current sea level (left). Inundation due to a storm surge produced by Hurricane Hazel and a 0.2m sea level rise (right).
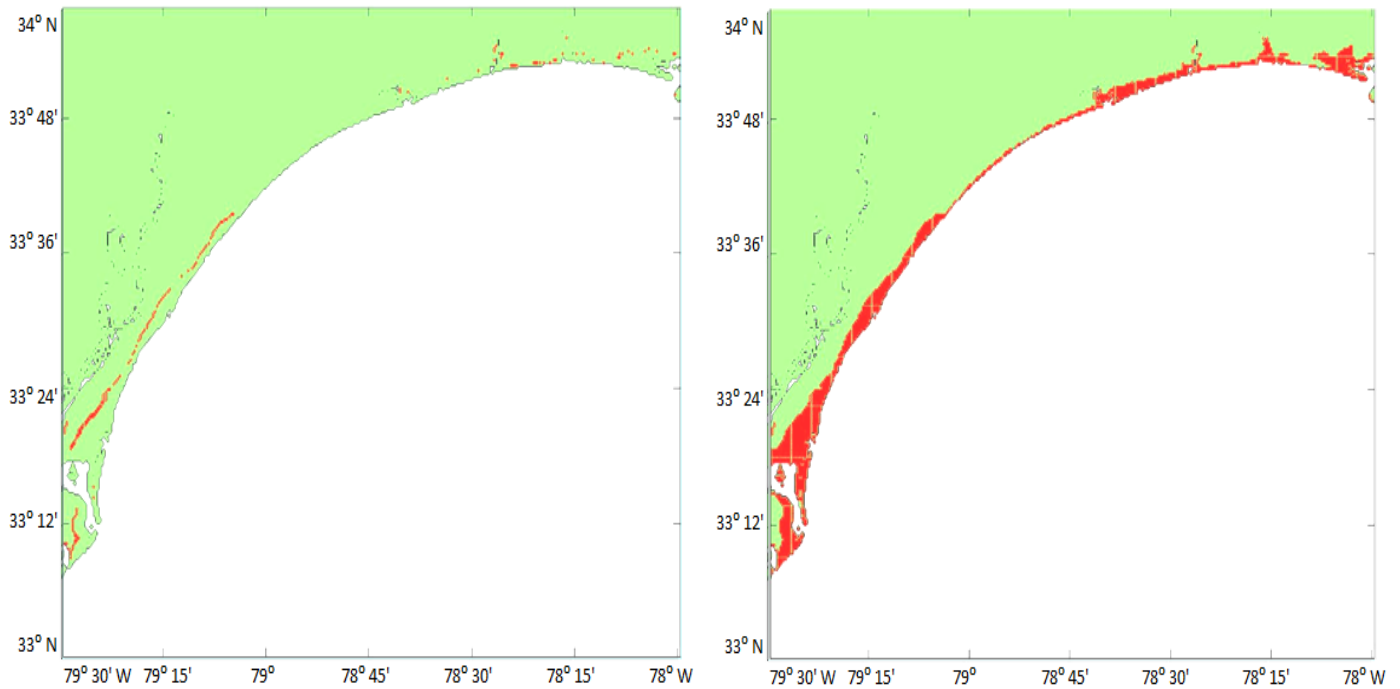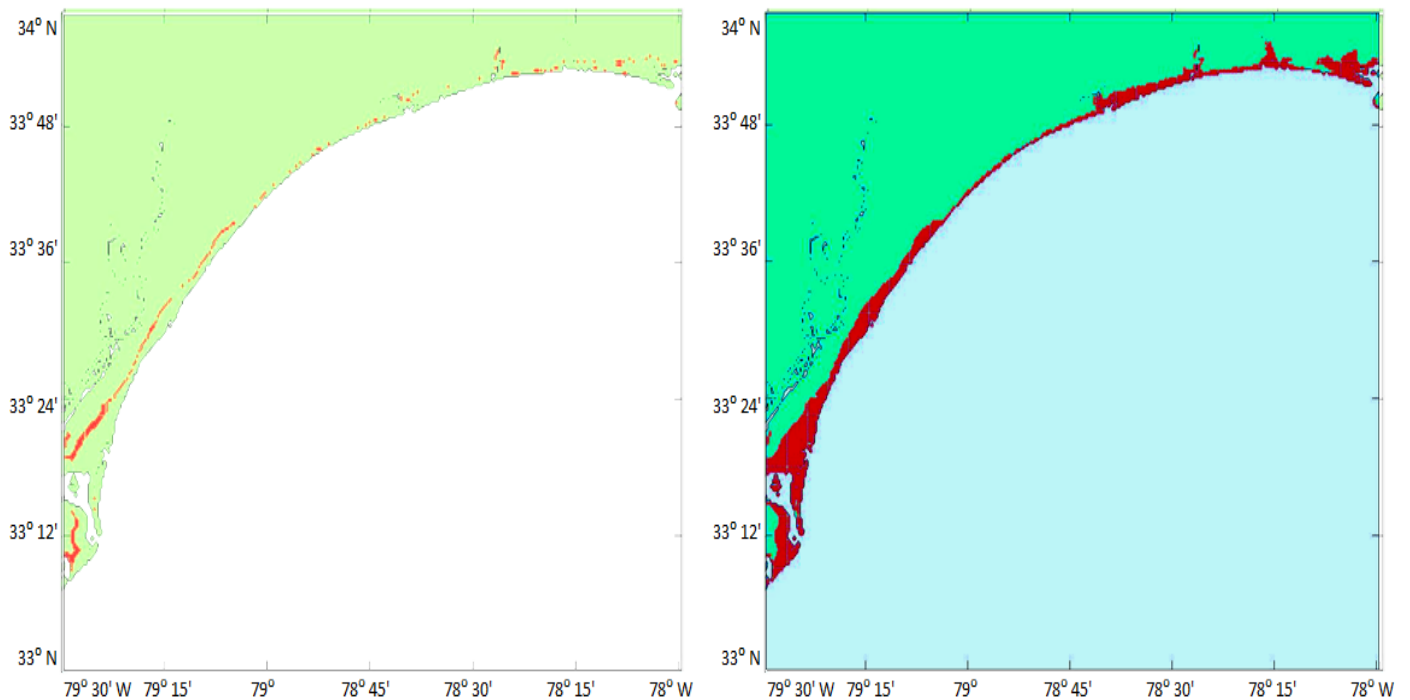
Figure 11. Coastal Inundation due to a 0.6m Rise in Sea Level, Along the South and North Carolina Coast. Inundation due to a 0.6m sea level rise, compared to current sea level (left). Inundation due to a storm surge produced by Hurricane Hazel and a 0.6m sea level rise (right).
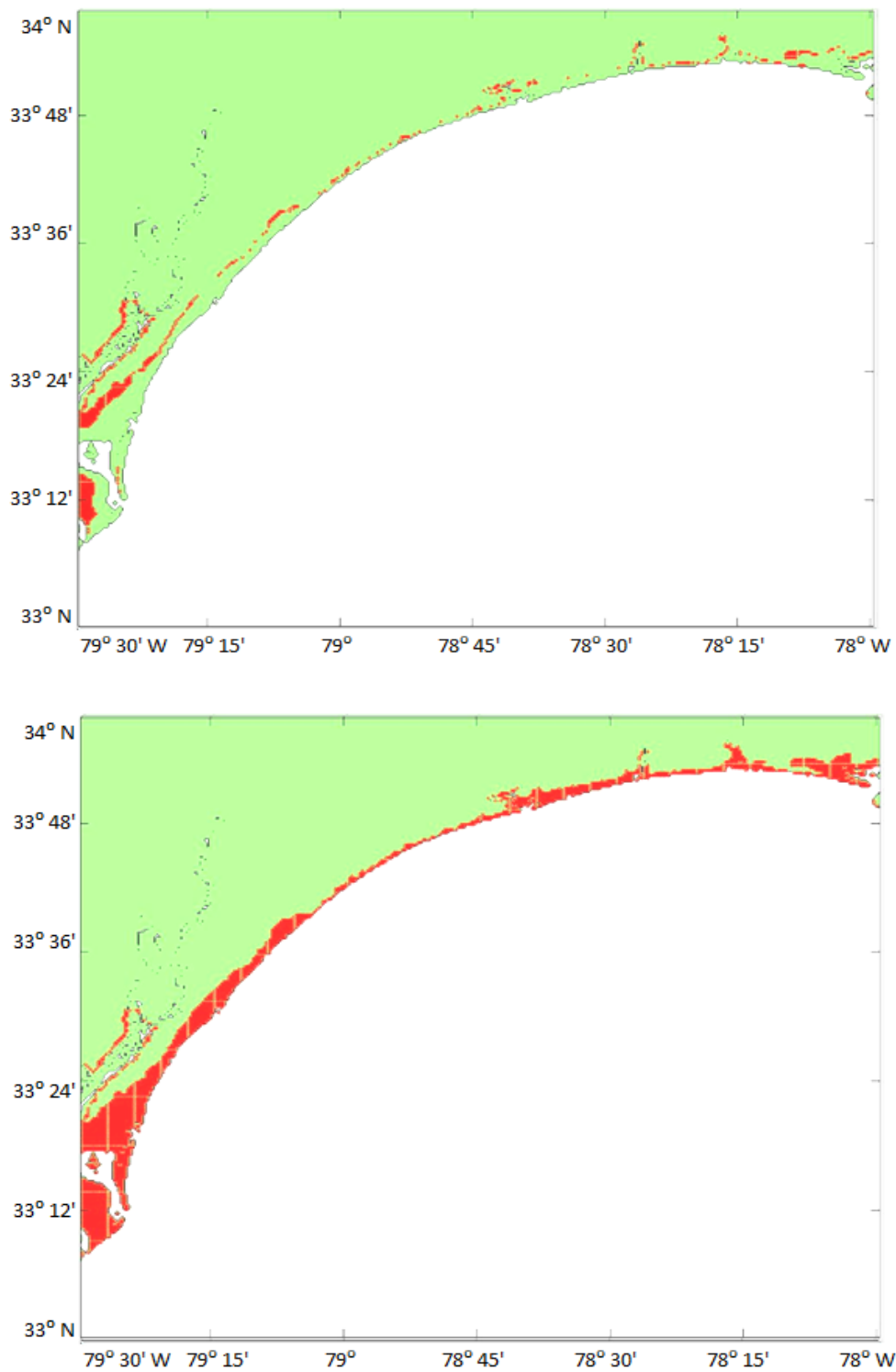

Figure 12. Coastal Inundation due to a 1.0m Rise in Sea Level, Along the South and North Carolina Coast. Inundation due to a 1.0m sea level rise, compared to current sea level (left). Inundation due to a storm surge produced by Hurricane Hazel and a 1.0m sea level rise (right).

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Figure 13. Coastal Inundation due to a 2.0m Rise in Sea Level, Along the South and North Carolina Coast. Inundation due to a 2.0m sea level rise, compared to current sea level (top). Inundation due to a storm surge produced by Hurricane Hazel and a 02.0m sea level rise (bottom).
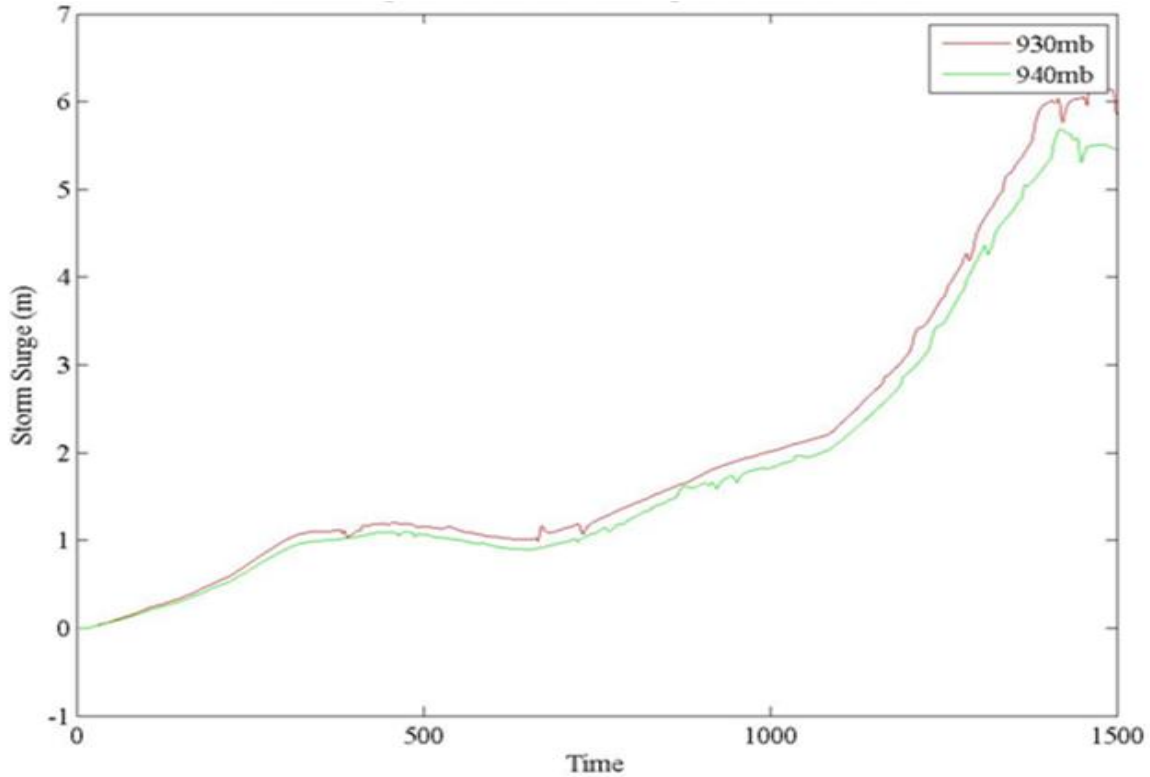
Figure 7. Storm Surge Produced during Landfall of Hurricane Hazel for Two Different Barometric Storm Pressures at 33.85°N, 78.57°W, where Every Time Step Represents 50 Seconds.
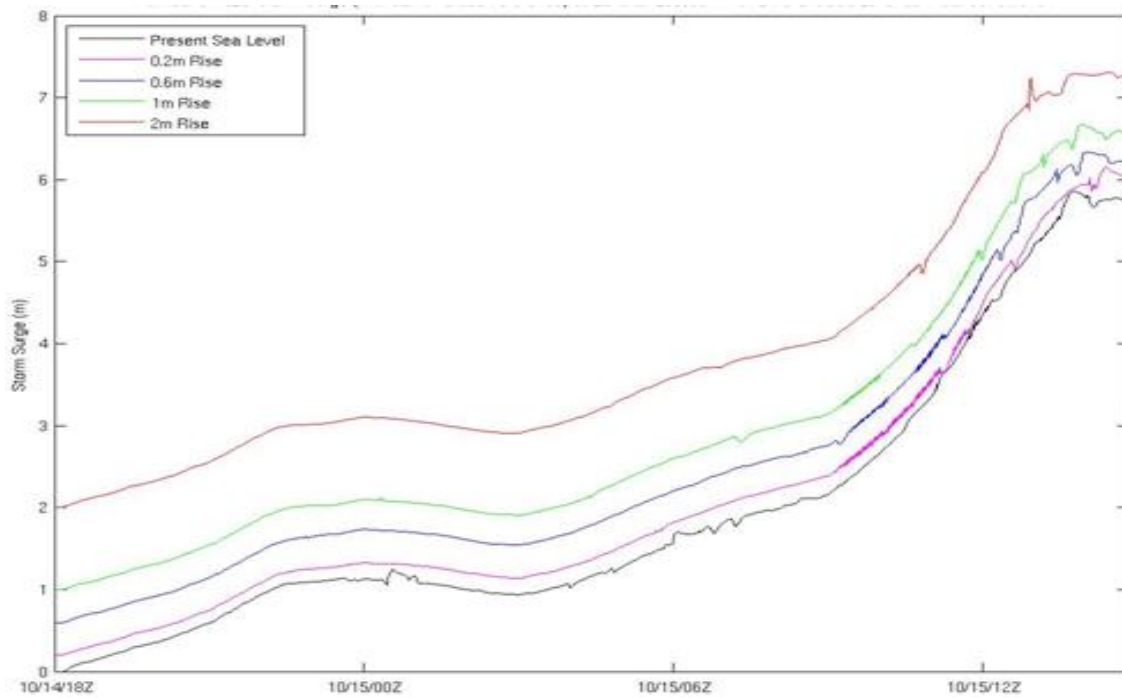

Figure 8. Storm Surge Produced during Landfall of Hurricane Hazel (940mb) at 33.85°N, 78.57°W for four Sea Level Rise Scenarios
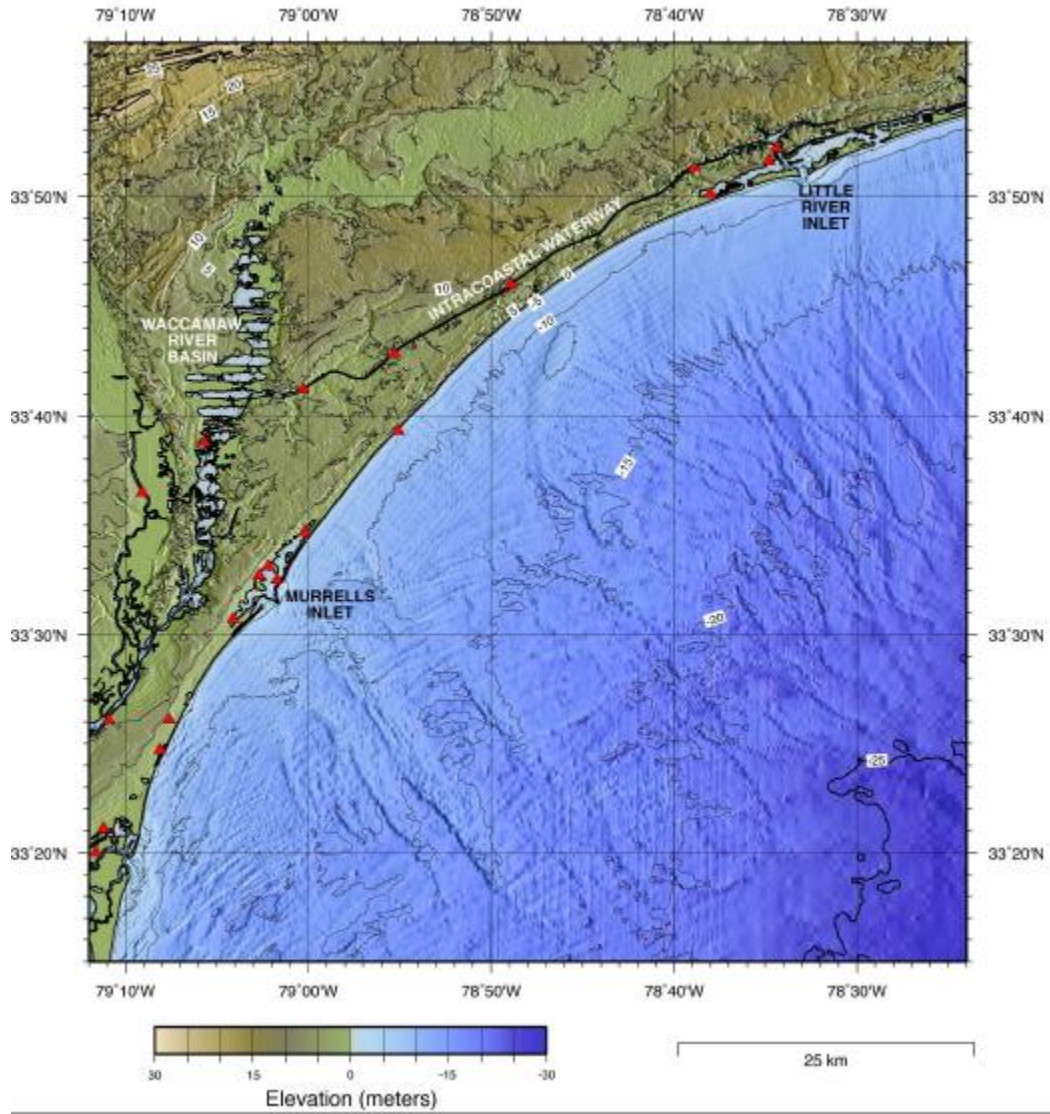
Figure 5. Topography and Bathymetry of the Grand Strand, South Carolina Area (Taylor et al., 2008)
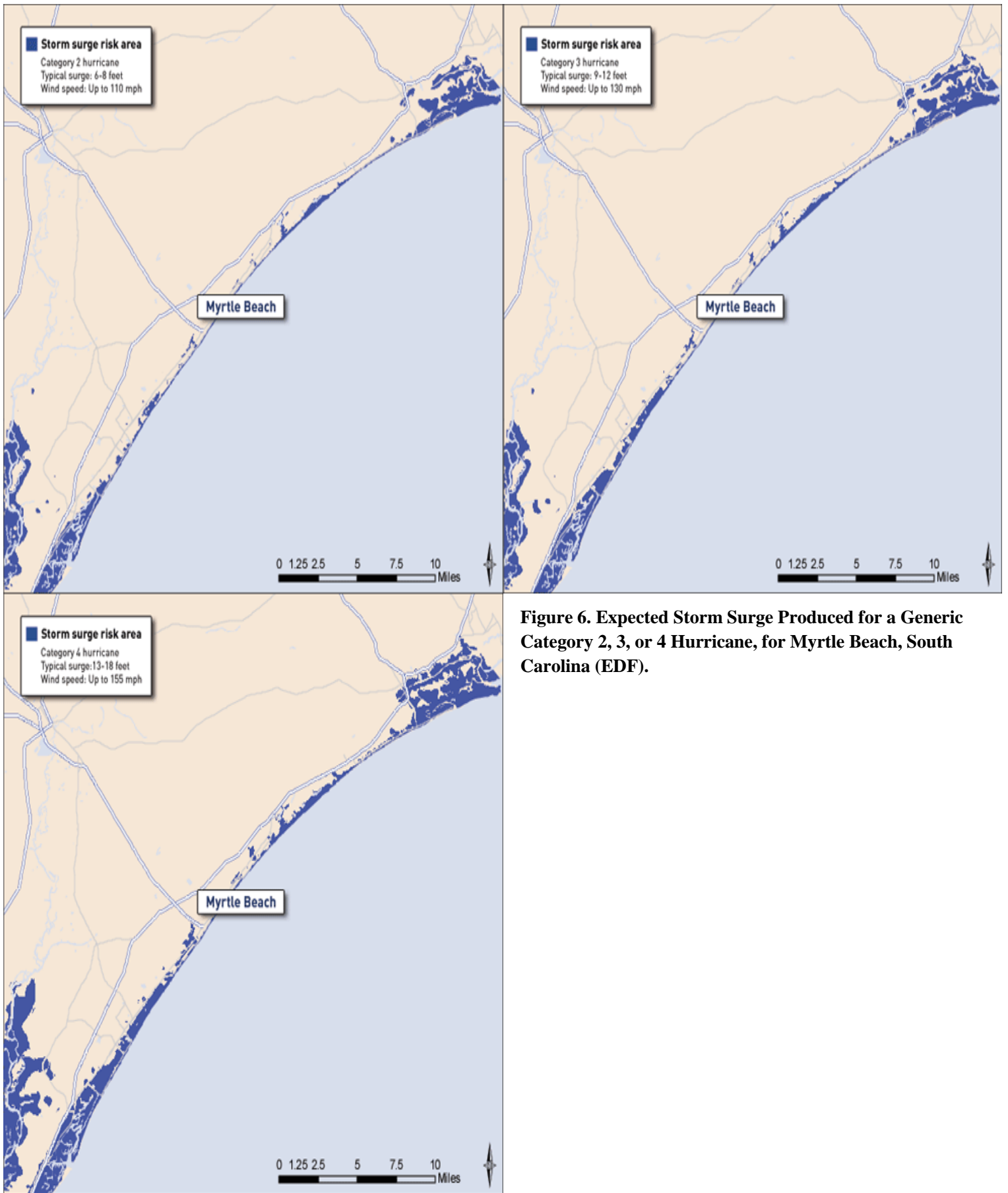
Figure 6. Expected Storm Surge Produced for a Generic Category 2, 3, or 4 Hurricane, for Myrtle Beach, South Carolina (EDF).

Works Cited

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