Florida Statewide Regional Evacuation Study Program

Directional Atlas

Gilchrist County

Volume 10-3

Book 3

Florida Division of Emergency Management

North Central Florida Regional Planning Council

North Central Florida Region

2015

Includes Hurricane Evacuation Study

Statewide Regional Evacuation Study Program

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NORTH CENTRAL FLORIDA STORM TIDE DIRECTIONAL ATLAS

Volume 10-3
Book 3 - Gilchrist County

This Atlas is part of Volume 10 of the ***Statewide Regional Evacuation Study Program*** (SRESP), and one of three sets of county books in the *North Central Florida Storm Tide Directional Atlas* series. Book 1 covers Dixie County; Book 2 covers Taylor County; and Books 3 and 4 cover the two inland Counties which receive storm surge: Gilchrist and Lafayette. In each county, the primary volume presents an overview of the study and the methodology, while the Appendices, numbered from A to C, include the surge inundation maps for each of three directional storm clusters. The Atlas maps identify those areas subject to potential storm tide flooding from the five categories of hurricane on the Saffir-Simpson Hurricane Wind Scale, as determined by the National Oceanic and Atmospheric Administration (NOAA) numerical storm surge model, Sea, Lake and Overland Surges from Hurricanes (SLOSH). Volume 10 is unique in that it is based on the direction the storm is heading and depicts the resulting surge of storms approaching from that specific directional angle.

The *Storm Tide Directional Atlas* series supplements the original hazards analysis for storm tides (Volume 7-3) and depth (Volume 9-3), and enhances a key component of the SRESP. The *Technical Data Report* (Volume 1-3) was built upon the original storm tide analysis and includes the evacuation zones and population estimates, results of the evacuation behavioral data, shelter analysis and evacuation transportation analysis. The study, which provides vital information to state and local emergency management, forms the basis for county evacuation plans. The final study documents are available on the Internet at:

http://www.ncfrpc.org/sres/directional/index.html

This Atlas series was produced by the North Central Florida Regional Planning Council with funding from the Federal Emergency Management Agency, through the Florida Division of Emergency Management.

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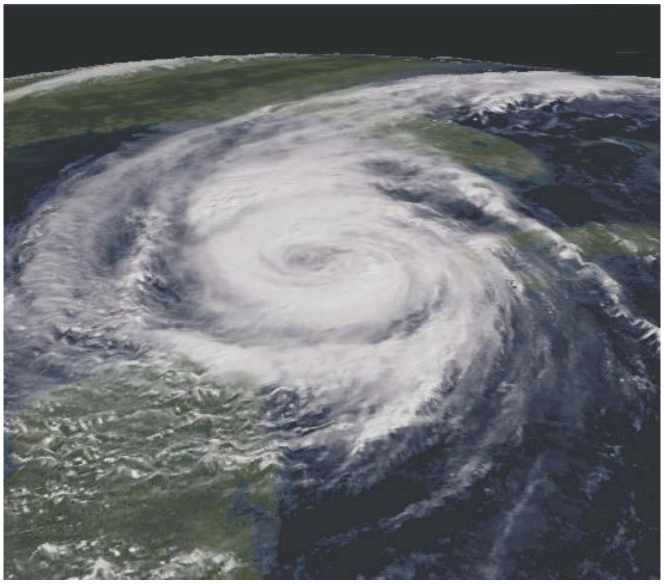


VOLUME 10-3
NORTH CENTRAL FLORIDA

STORM TIDE DIRECTIONAL ATLAS
Book 3
Gilchrist County

Table of Contents

List of Tables

List of Figures

List of Map Appendices

A. Introduction

A comprehensive emergency management program requires attention to four key inter-related components: preparedness, response, recovery and mitigation. Preparing and avoiding or reducing potential loss of life and property damage – **preparedness and mitigation** – requires accurate and precise hazard and vulnerability analyses. These analyses are the foundation for evacuation and disaster response planning, as well as the development of local mitigation strategies designed to reduce the community's overall risk to disasters. This Atlas series provides information to state, county and local emergency management officials and planners for use in hurricane preparedness and coastal management in the North Central Florida Region, including Dixie, Taylor, Lafayette and Gilchrist Counties (Figure 1). It is part of a statewide effort to enhance our ability to respond to a hurricane threat, facilitate the evacuation of vulnerable residents to a point of relative safety and mitigate our vulnerability in the future. The ***Statewide Regional Evacuation Study Program*** provides a consistent, coordinated and improved approach to addressing the state and regional vulnerability to the hurricane threat.

The specific purpose of this Atlas is to provide maps that depict storm tide heights and the extent of still water, storm surge coastal flooding inundation from hurricanes of five different intensities and from five selected directions in the North Central Florida area. The Atlas was prepared by the North Central Florida Regional Council as part of the *Statewide Regional Evacuation Study Program.* The Study is a cooperative effort of the Florida Department of Economic Opportunity, the Division of Emergency Management, the Florida Regional Planning Councils and the county emergency management agencies.

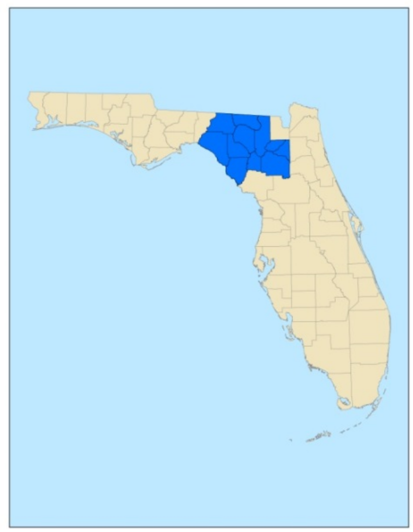
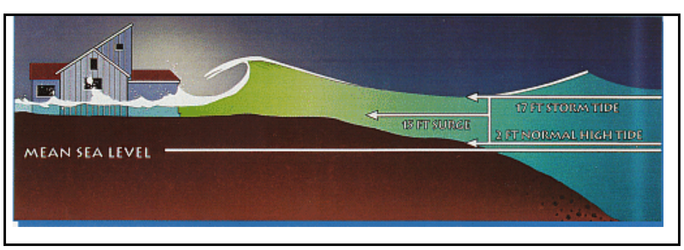


Figure 1 The North Central Florida Region

B. The SLOSH Model

The principal tool utilized in this study for analyzing the expected hazards from potential hurricanes affecting the study area is the Sea, Lake and Overland Surges from Hurricanes (**SLOSH**) numerical storm surge prediction model. The SLOSH computerized model predicts the storm tide heights that result from hypothetical hurricanes with selected various combinations of pressure, size, forward speed, track and winds. Originally developed for use by the National



Hurricane Center (NHC) as a tool to give geographically specific warnings of expected surge heights during the approach of hurricanes, the SLOSH model is utilized in regional studies for several key hazard and vulnerability analyses.
The SLOSH modeling system consists of the model source code and the model basin or grid. SLOSH model grids must be developed for each specific geographic coastal area, individually incorporating the unique local bay and river configuration, water depths, bridges, roads and other physical features. In addition to open coastline heights, one of the most valuable outputs of the SLOSH model for evacuation planning is its predictions of surge heights over land into inland areas.

The Tampa Bay SLOSH model basin completed in 1979 represented the first application of SLOSH storm surge dynamics to a major coastal area of the United States. The model was developed by the Techniques Development Lab of the National Oceanic and Atmospheric Administration (NOAA), under the direction of the late Dr. Chester P. Jelesnianski. In December 1990 the National Hurricane Center updated the SLOSH model. A major improvement to the model was the incorporation of wind speed degradation overland as the simulated storms moved inland. This duplicated the pressure "filling" and increases in the radii of maximum winds (RMW) as the hurricanes weaken after making landfall. The grid configuration also provided more detail and additional information.

The newest generation of the SLOSH model basin incorporated in the 2010 Statewide Regional Evacuation Study Program reflects major improvements, including higher resolution basin data and grid configurations. Faster computer speeds allowed additional hypothetical storms to be run for creation of the MOMs[1] or the maximum potential storm tide values for each category of storm. For this atlas, MEOWS[2] were used to create the surge inundation.

1. Hypothetical Storm Simulations

Surge height depends strongly on the specifics of a given storm, including forward speed, angle of approach, intensity or maximum wind speed, storm size, storm shape and landfall location. The SLOSH model was used to develop data for various combinations of hurricane strength, wind speed and direction of movement. Storm strength was modeled using the central pressure (defined as the difference between the ambient sea level pressure and the minimum value in the storm's center), the storm eye size and the radius of maximum winds using the five categories of hurricane intensity as depicted in the Saffir-Simpson Hurricane Wind Scale (see Table 1). The modeling for each tropical storm/hurricane category was conducted using the mid-range pressure difference ($\triangle$p, millibars) for that category. The model also simulates the storm filling (weakening upon landfall) and radius of maximum winds (RMW) increase.

Ten storm track headings (E, ENE, NE, NNE, N, NNW, NW, WNW, W and WSW) were selected as being representative of storm behavior in the North Central Florida region, based on observations by forecasters at the National Hurricane Center. For each set of tracks in a specific direction storms were run at forward speeds of 5, 15 and 25 mph. And for each direction, at each speed, storms were run at two different sizes (30 statute miles

[1] Maximum of MEOWs or Maximum of Maximums
2 Maximum Envelope Of Water

radius of maximum winds and 45 statute miles radius of maximum winds). Finally, each scenario was run at both mean tide and high tide. Both tide levels are now referenced to North American Vertical Datum of 1988 (NAVD88) as opposed to the National Geodetic Vertical Datum of 1929 (NGVD29) used in previous studies.

Table 1 Saffir-Simpson Hurricane Wind Scale

Category	Wind Speeds	Potential Damage
Category 1	Sustained winds 74-95 mph	*Very dangerous winds will produce some damage*
Category 2	Sustained winds 96-110 mph	*Extremely dangerous winds will cause extensive damage*
Category 3	Sustained winds 111-130 mph	*Devastating damage will occur*
Category 4	Sustained winds 131-155 mph	*Catastrophic damage will occur*
Category 5	Sustained winds of 156 mph and above	*Catastrophic damage will occur*

A total of 16,242 runs were made, consisting of the different parameters shown in Table 2. This includes: Directions, speeds, sizes, (Saffir/Simpson) intensities, number of tracks and the number of runs.

Table 2 Cedar Key Basin Hypothetical Storm Parameters

Direction	Speeds (mph)	Size (Radius of Maximum winds)	Intensity	Tides	Tracks	Runs
W	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	23	1380
WNW	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	31	1860
NW	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	22	1320
NNW	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	22	1320
N	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	24	1584

Table 2 Cedar Key Basin Hypothetical Storm Parameters (Continued)

Direction	Speeds (mph)	Size (Radius of Maximum winds)	Intensity	Tides	Tracks	Runs
NNE	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	30	1980
ENE	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	36	2376
E	5,15,25 - mph	20 statute miles; 35 statute miles	1 through 5	Mean / High	31	2046
TOTAL						16,242

2. The Grid for the Cedar Key SLOSH Model

Figure 2 illustrates the area covered by the grid for the Cedar Key SLOSH Model. To determine the surge values the SLOSH model uses a telescoping elliptical grid as its unit of analysis with 157 arc lengths (1< I < 157) and 169 radials (1< J < 169). Use of the grid configuration allows for individual calculations per grid square, which is beneficial in two ways: (1) it provides increased resolution of the storm surge at the coastline and inside the harbors, bays and rivers, while decreasing the resolution in the deep water where detail is not as important; and (2) it allows economy in computation.

The grid size for the Cedar Key model varies from approximately 0.1 square miles or 63 acres closest to the pole (I = 1) to the grids on the outer edges (Gulf of Mexico) where each grid is approximately 5 square miles.

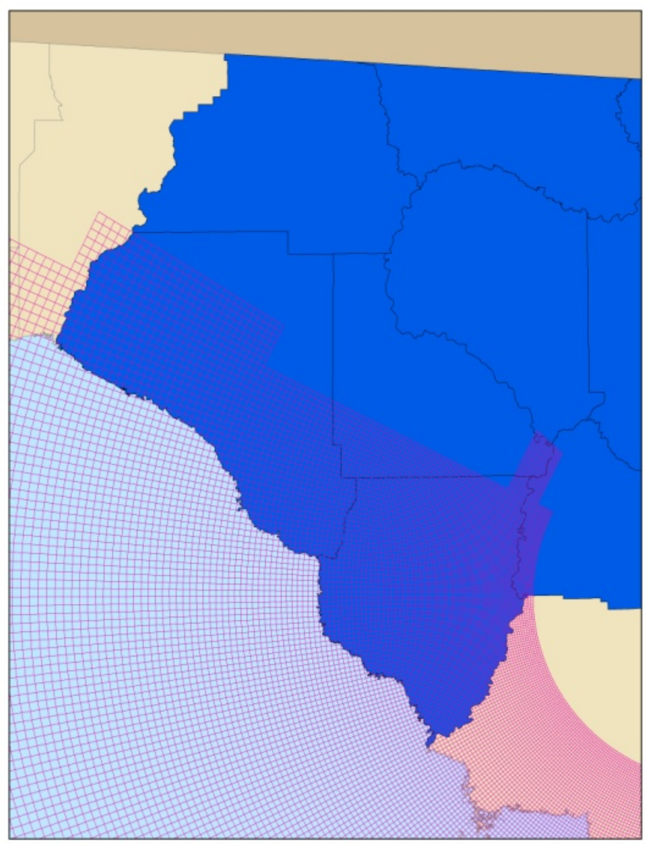


Figure 2 Cedar Key Basin Grid

3. Storm Scenario Determinations

As indicated, the SLOSH model is the basis for the "hazard analysis" portion of coastal hurricane evacuation plans. Thousands of hypothetical hurricanes are simulated with various Saffir-Simpson Wind categories, forward speeds, landfall directions, and landfall locations. An envelope of high water containing the maximum value a grid cell attains is generated at the end of each model run. These envelopes are combined by the NHC into various composites which depict the possible flooding. One useful composite is the MEOW (Maximum Envelopes of Water), which incorporates all the envelopes for a particular category, speed, and landfall direction. Once surge heights have been determined for the appropriate grids, the maximum surge heights are plotted by storm track and tropical storm/hurricane category.

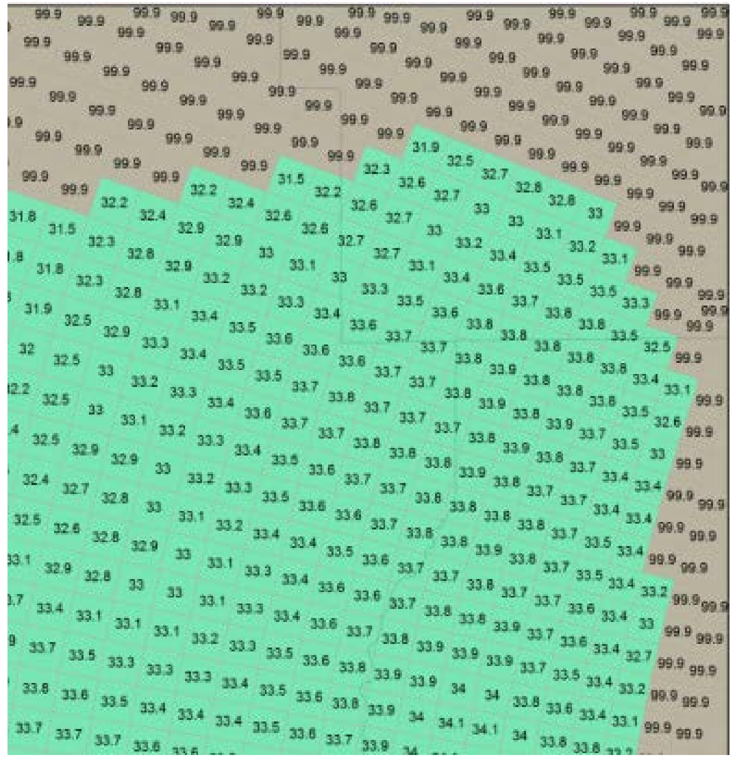


Figure 3 SLOSH Grid with Surge Values

These MEOWs, or Reference Hurricanes, can be used by emergency managers in evacuation decision-making when and if sufficient forecast information is available to project storm track or type of storm (different landfalling, paralleling, or exiting storms). However, in order to determine a scenario which may confront the county in a hurricane threat 24-48 hours before a storm is expected, a further compositing of the MEOWs into Maximums of the Maximums (MOMs) is usually required. MEOWs are used in this atlas instead of the MOMs.

The MOM (Maximum of the MEOWs) combines all the MEOWs of a particular category. The MOMs represent the maximum surge expected to occur at any given location, regardless of the specific storm track/direction of the hurricane. The only variable is the intensity of the hurricane represented by category strength (Category 1-5). On the other hand, the MEOWs represent the maximum surge expected to occur at any given location with the storm moving in a specific direction and speed.

The MEOW and MOM surge heights, which were furnished by the National Hurricane Center, have 2 values, mean tide and high tide. Mean tide has 0' tide correction. High tide has a 1' tide correction added to it. The Storm Tide limits include the adjustment for mean high tide. All elevations are now referenced to the NAVD88 datum.

4. Directional Clusters

The Statewide Regional Evacuation Study Program continues to evolve as technology and data allows. Volume 10, the Directional Storm Tide Atlas, utilizes a hybrid of the SLOSH output data and creates clustered MEOWs, which are referred to as DOMs (Directions of Maximums). Each DOM is a cluster of MEOWs in a generalized direction retaining the aggregated maximum SLOSH values from those individual compass directions and all forward speeds. **Figure 4** illustrates compass headings that make up the MEOWs.

The Emergency Management staff for each region met and determined which MEOW clusters should be analyzed for their region. **Figures 5 and 6** illustrate the cluster choices and directions analyzed in each cluster. The arrows indicated the direction in which the storm is ***heading toward***. Emergency Management staff reviewed these clusters and determined which clusters would best represent likely hurricane scenarios in their region. Many regions chose clusters that corresponded to landfalling, paralleling, and exiting storms most likely to occur in their region of Florida.

Each region's choices were different, including which set of clusters (8-cluster version vs. the 4-cluster version) was used and the number of clusters that were chosen to be analyzed.

North Central Florida emergency managers met on June 17, 2014, and selected three clusters for analysis of each county: N-ENE, SW-WNW, and WNW-N. These are approaching, exiting, and paralleling tracks.

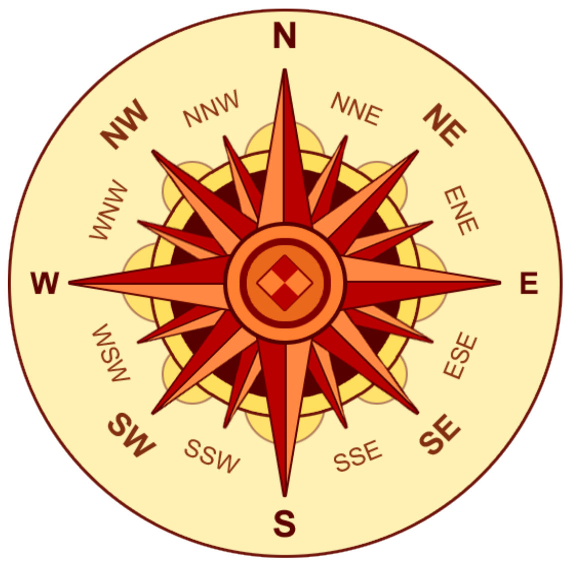


Figure 4: Compass Directions for Directional Atlas

Cluster Number	Directions Analyzed
1	N-NE
2	NE-E
3	E-SE
4	SE-S
5	S-SW
6	SW-W
7	W-NW
8	NW-N

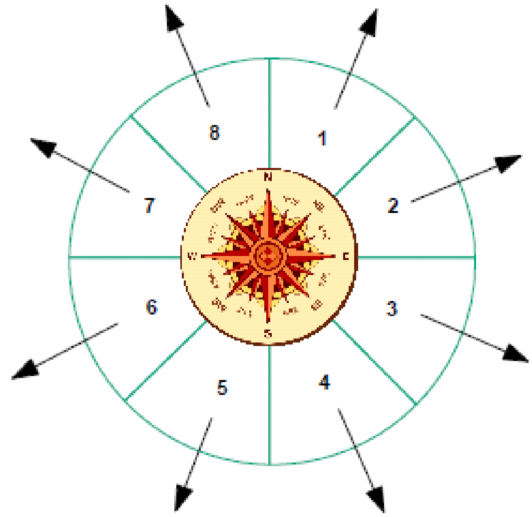


Figure 5: Directional Atlas Clusters: 8-Cluster version

Cluster Number	Directions Analyzed
1	SW-WNW
2	WNW-N
3	N-ENE
4	ENE-SE

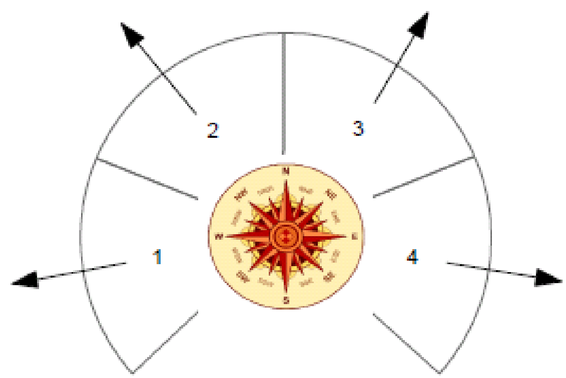


Figure 6: Directional Atlas Clusters: 4-Cluster version

The map sets in this Atlas are broken down by direction. Each county has its own book series that includes all directions analyzed for that particular county. This Atlas shows for the first time how a theoretical storm moving in a particular direction could inundate the landscape in a worst case scenario for this region.

These surge heights were provided within the SLOSH grid system as illustrated in Figure 2. The range of maximum surge heights (low to high) for each scenario is provided for each category of storm (MOM) in Table 3. **It should be noted again that these surge heights represent the maximum surge height recorded in the county from the storm tide analysis, including inland, riverine and back bay areas where the surge can be magnified dependent upon storm parameters.**

Table 3 Potential Directional Storm Tide Heights by County

(In feet above NAVD88)

*Storm Strength	Dixie	Taylor	Gilchrist	Lafayette
N-ENE (Approaching)				
1	Up to 10.6	Up to 11.1	Up to 5.7	0
2	Up to 17.4	Up to 19.5	Up to 14.9	0
3	Up to 23.6	Up to 27.7	Up to 21.7	0
4	Up to 29.3	Up to 33.5	Up to 29.5	Up to 28.3
5	Up to 34.2	Up to 38.5	Up to 31.8	Up to 33.8
SW-WNW (Exiting)				
1	Up to 3.3	Up to 4.1	Up to 2.9	0
2	Up to 4.9	Up to 6.9	Up to 3.3	0
3	Up to 7.3	Up to 10.8	Up to 4.5	0
4	Up to 8.5	Up to 12.7	Up to 5.2	0
5	Up to 9.1	Up to 13.4	Up to 5.4	0
WNW-N (Paralleling)				
1	Up to 8.6	Up to 10.5	Up to 4.7	0
2	Up to 15.1	Up to 19.0	Up to 10.4	0
3	Up to 20.8	Up to 27.1	Up to 19.0	0
4	Up to 26.3	Up to 32.8	Up to 23.5	Up to 25.1
5	Up to 31.5	Up to 37.6	Up to 29.1	Up to 30.8

** Based on the category of storm on the Saffir-Simpson Hurricane Wind Scale*
*** Surge heights represent the maximum values from SLOSH MOMs.*

Table 4 Potential Directional Storm Tide Depths by County

(In feet above ground level)

*Storm Strength	Dixie	Taylor	Gilchrist	Lafayette
N-ENE (Approaching)				
1	Up to 10.5	Up to 10.8	Up to 4.2	0
2	Up to 17.4	Up to 19.1	Up to 13.0	0
3	Up to 24.6	Up to 25.7	Up to 20.1	0
4	Up to 28.8	Up to 32.8	Up to 25.2	Up to 4.3
5	Up to 33.7	Up to 36.7	Up to 30.1	Up to 10.3
SW-WNW (Exiting)				
1	Up to 4.0	Up to 4.5	Up to 1.5	0
2	Up to 6.8	Up to 7.3	Up to 1.8	0
3	Up to 8.0	Up to 10.6	Up to 3.0	0
4	Up to 9.2	Up to 12.5	Up to 3.9	0
5	Up to 9.3	Up to 13.0	Up to 4.0	0
WNW-N (Paralleling)				
1	Up to 8.7	Up to 10.4	Up to 3.2	0
2	Up to 15.0	Up to 18.4	Up to 8.6	0
3	Up to 20.7	Up to 25.7	Up to 17.5	0
4	Up to 26.0	Up to 32.3	Up to 21.9	Up to 1.0
5	Up to 31.1	Up to 36.6	Up to 27.7	Up to 8.6

** Based on the category of storm on the Saffir-Simpson Hurricane Wind Scale*
*** Surge heights represent the maximum values from SLOSH MOMs.*

C. Creation of the Storm Tide Zones

The maps in this atlas depict SLOSH-modeled heights of storm tide and extent of flood inundation for hurricanes of five different intensities. As indicated above, the storm tide was modeled using the Maximum of Maximums (MOMs) representing the potential flooding from the five categories of storm intensity of the Saffir-Simpson Hurricane Wind Scale.

1. Determining Storm Tide Height and Flooding Depth

SLOSH and SLOSH-related products reference storm tide heights relative to the model vertical datum, NAVD88. In order to determine the inundation depth of surge flooding at a particular location the ground elevation (relative to NAVD88) at that location must be subtracted from the potential surge height.[3]

Surge elevation, or water height, is the output of the SLOSH model. At each SLOSH grid point, the maximum surge height is computed at that point.

Within the SLOSH model an average elevation is assumed within each grid square. Height of water above terrain was not calculated using the SLOSH average grid elevation because terrain height may vary significantly within a SLOSH grid square. For example, the altitude of a 1-mile grid square may be assigned a value of 1.8 meters (6 feet), but this value represents an average of land heights that may include values ranging from 0.9 to 2.7 meters (3 to 9 feet).

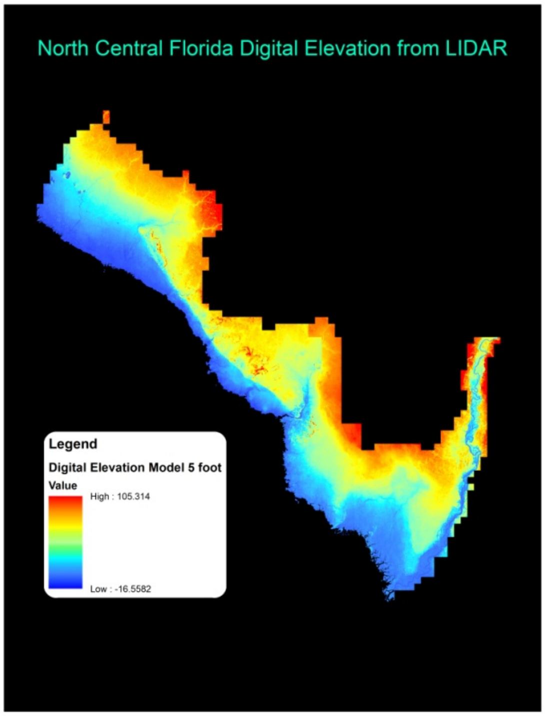


Figure 7 Digital Elevation from LIDAR

In this case, a surge value of 2.5 meters (8 feet) in this square would imply a 0.7 meters (2 feet) average depth of water over the grid's terrain. However, in reality within the grid area portion of the grid would be "dry" and other parts could experience as much as 1.5 meters (5 feet) of inundation. Therefore, in order to determine the storm tide limits, the depth of surge flooding above terrain at a specific site in the grid square is the result of subtracting the terrain height determined by remote sensing from the model-generated storm tide height in that grid square.[4]

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[3] It is important to note that one must use a consistent vertical datum when post-processing SLOSH storm surge values.

[4] Note: This represents the regional post-processing procedure. When users view SLOSH output within the SLOSH Display Program, the system uses average grid cell height when subtracting land.

2. Storm Tide Post-Processing

The Atlas was created using a Toolset wrapped into ESRI's ArcGIS mapping application, ArcMap. The surge tool was developed for the Statewide Regional Evacuation Study Program by the Tampa Bay Regional Planning Council, which had used a similar tool for the previous Evacuation Study Update (2006). This tool enabled all regions within the state of Florida to process the SLOSH and elevation data with a consistent methodology.

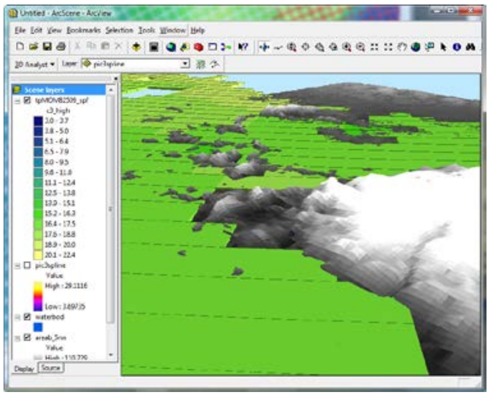


Figure 8 SLOSH Display

The tool basically performs the operation of translating the lower resolution SLOSH grid data (Figure 8) into a smooth surface resembling actual storm tide and terrain, processing it with the high resolution elevation data derived from LiDAR. The image on the left represents how the data would look as it appears directly from SLOSH Model output.

Processing all the data in the raster realm, the tool is able to digest large amounts of data and output detailed representations of surge inundation.

Unlike previous surge model applications, this model creates a DOM basin for each of the chosen directions before model processing begins. For each clustered direction there would be a basin with maximum surge height values for each category and an accompanying atlas. The program first interpolates the SLOSH height values for each category into a raster surface using spline interpolation. This type of interpolation is best for smooth surfaces, such as water and slow changing terrain. The result is a raster surface representing the surge height for a category that can be processed against the raster Digital Elevation Model from the LIDAR. The "dry" values (represented as 99.9 in the SLOSH Model) are replaced by an average of the inundated grids surrounding the current processed grid. An algorithm performs this action utilizing the range of values in the current category of storm being processed.

Using this methodology, once the elevation is subtracted from the projected storm tide, the storm tide limits are determined. The output of the tool is a merged polygon file holding all the maximum inundation zones for Category 1 through Category 5. The output depicted in this Storm Tide Atlas is determined consistent with the coastal areas throughout the state. Figures 10-A, 10-B, and 10-C present a compilation of the *Storm Tide Atlas* for each county for each of the three different directional clusters analyzed for North Central Florida.

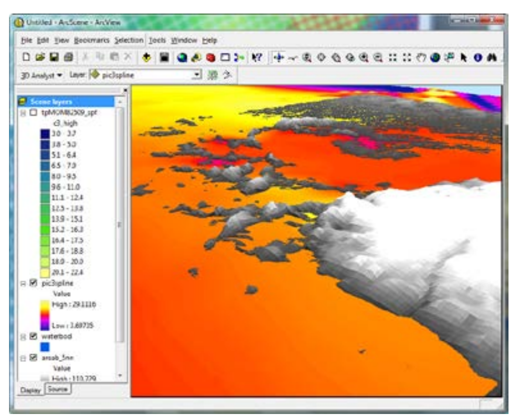


Figure 9 SLOSH Display Post-Processing

Figure 10-A Directional N-ENE (Approaching) Storm Surge for the North Central Florida Region

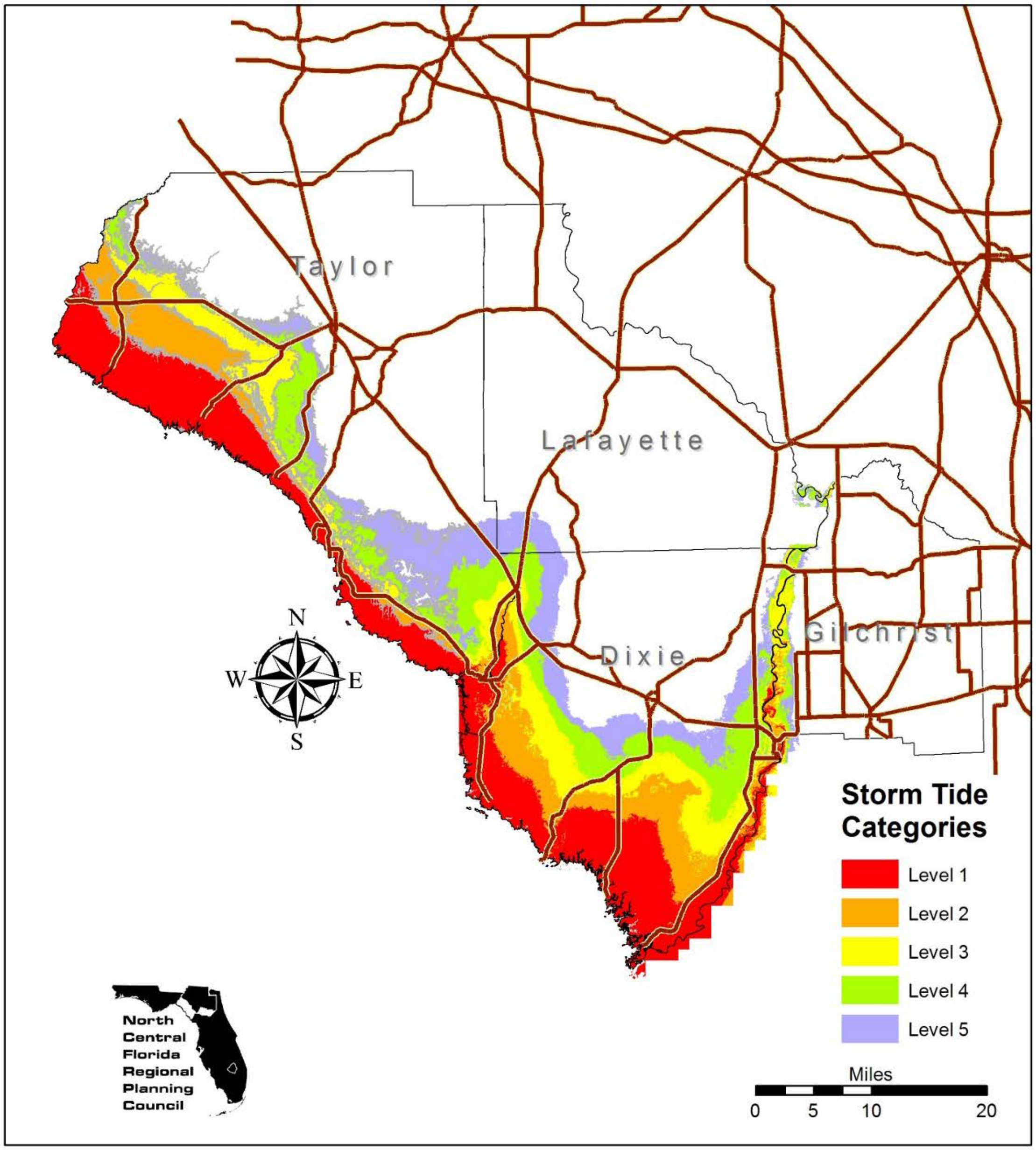


Figure 10B Directional SW-WNW (Exiting) Storm Surge for the North Central Florida Region

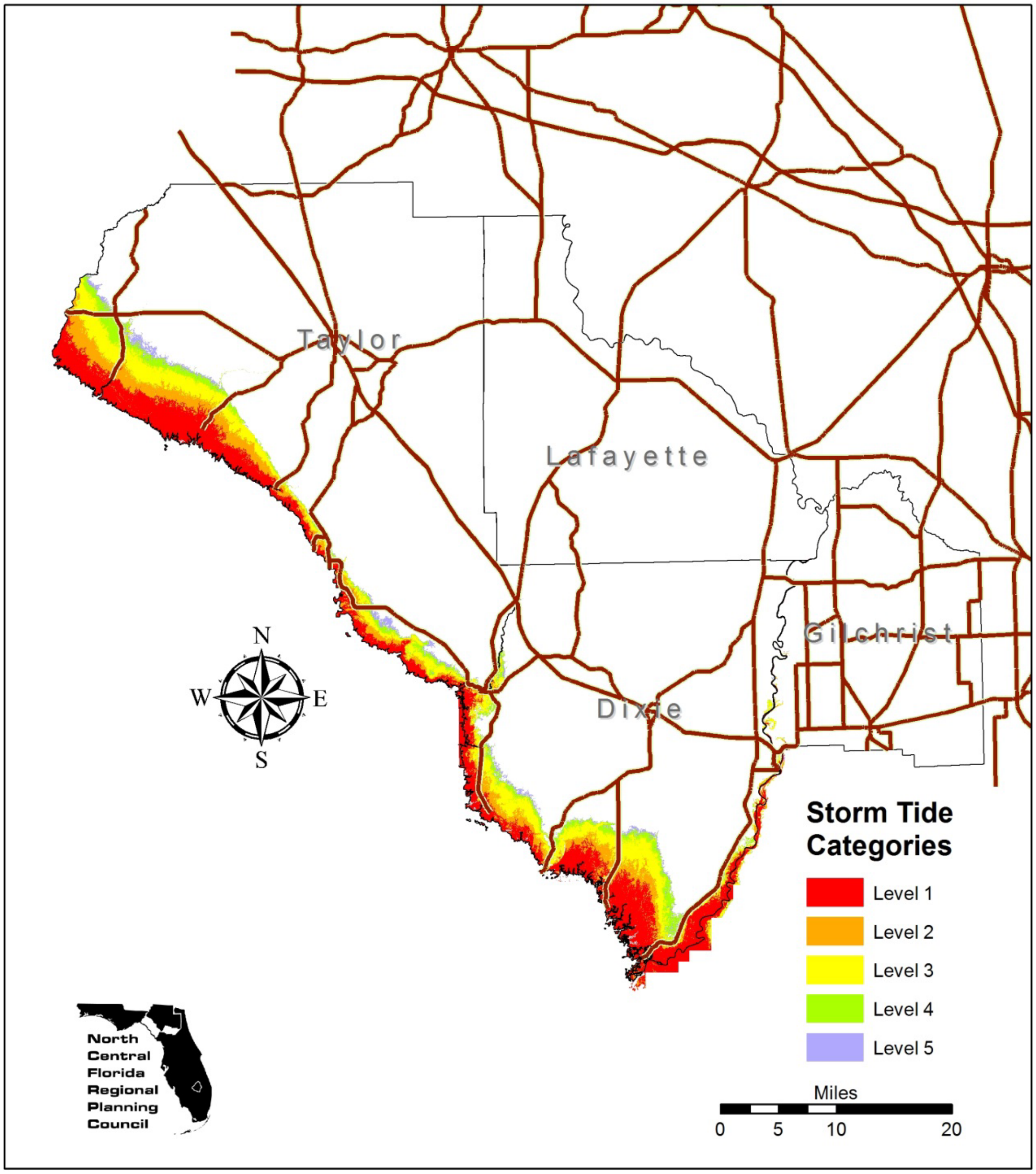
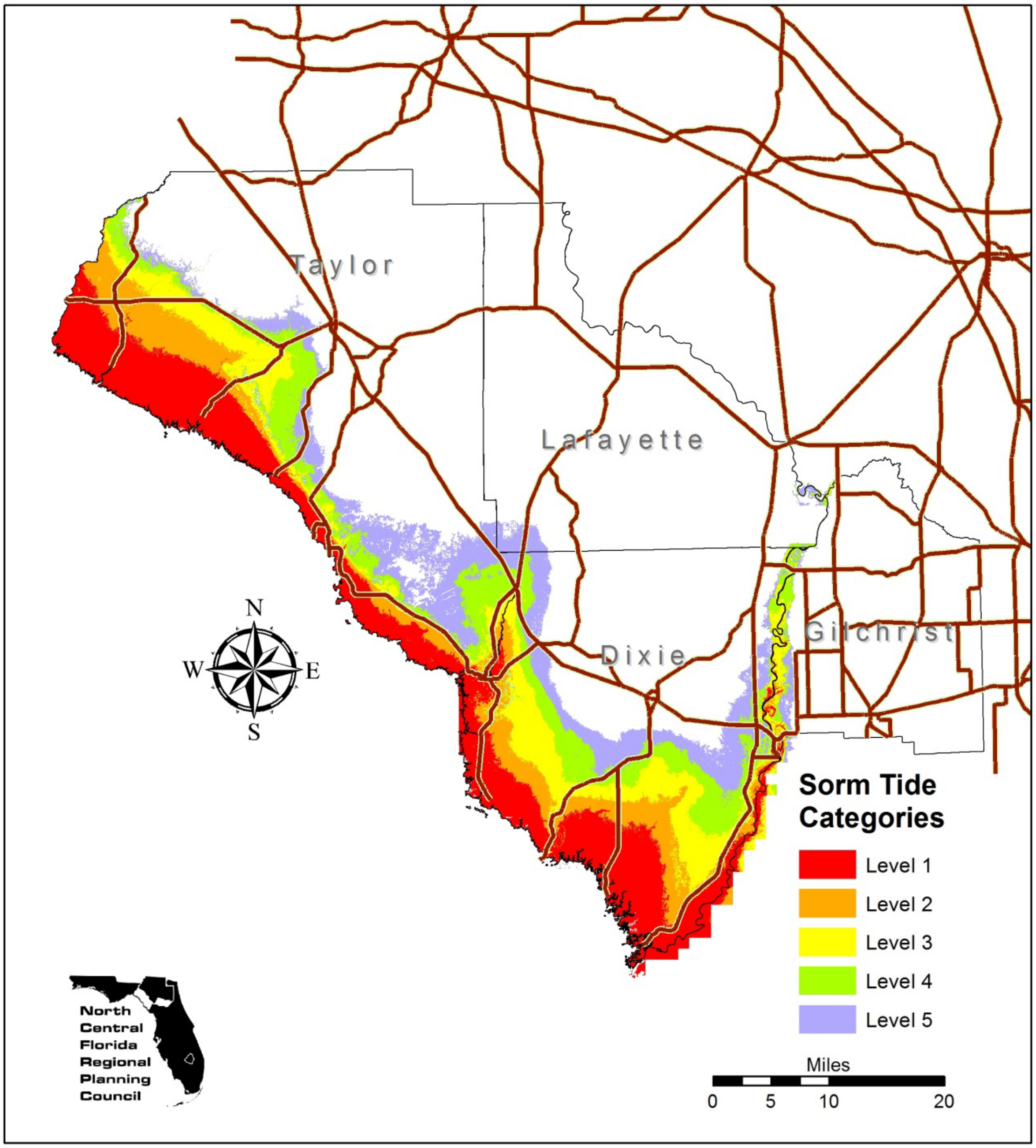


Figure 10C Directional WNW-N (Paralleling) Storm Surge for the North Central Florida Region



D. Variations to Consider

Variations between modeled versus actual measured storm tide elevations are typical of current technology in coastal storm surge modeling. In interpreting the data emergency planners should recognize the uncertainties characteristic of mathematical models and severe weather systems such as hurricanes. The storm tide elevations developed for this study and presented in the ***Directional Storm Tide Atlas*** should be used as guideline information for planning purposes.

1. Storm Tide and Wave Height

Regarding interpretation of the data, it is important to understand that the configuration and depth (bathymetry) of the Ocean or Gulf bottom will have a bearing on surge and wave heights. A narrow shelf, or one that drops steeply from the shoreline and subsequently produces deep water in close proximity to the shoreline tends to produce a lower surge but a higher and more powerful wave. Those regions that have a gently sloping shelf and shallower normal water depths, can expect a higher surge but smaller waves. The reason this occurs is because a surge in deeper water can be dispersed down and out away from the hurricane. However, once that surge reaches a shallow gently sloping shelf it can no longer be dispersed away from the hurricane; consequently water “piles up” as it is driven ashore by the wind stresses of the hurricane. Wave height is NOT calculated by the SLOSH model and is not reflected within the storm tide delineations.

2. Forward Speed

Under actual storm conditions it may be expected that a hurricane moving at a slower speed could have higher coastal storm tides than those depicted from model results. At the same time, a fast moving hurricane would have less time to move storm surge water up river courses to more inland areas. For example, a minimal hurricane or a storm further off the coast, such as Hurricane Elena (1985), which stalled 90 miles off the Tampa Bay coast for several tidal cycles, could cause extensive beach erosion and move large quantities of water into interior lowland areas. In the newest version of the SLOSH model, for each set of tracks in a specific direction, storms were run at forward speeds of 5, 15 and 25 mph.

3. Radius of Maximum Winds

As indicated previously, the size of the storm or radius of maximum winds (RMW) can have a significant impact on storm surge especially in bay areas and along the Gulf of Mexico. All of the hypothetical storms were run at two different sizes, 30 nautical mile radius of maximum winds and 45 nautical mile radius of maximum winds.

4. Astronomical Tides

Surge heights were provided by NOAA for both mean tide and high tide. Both tide levels are referenced to North American Vertical Datum of 1988. The storm tide limits reflect high tide in the region.

5. Accuracy

As part of the Statewide Regional Evacuation Study, all coastal areas, as well as areas surrounding Lake Okeechobee, were mapped using remote-sensing laser terrains mapping (LiDAR[5]) providing the most comprehensive, accurate and precise topographic data for this analysis. As a general rule, the vertical accuracy of the laser mapping is within a 15 centimeter tolerance. However, it should be noted that the accuracy of these elevations is limited to the precision and tolerance in which the horizontal accuracy for any given point is recorded. Other factors such as artifact removal algorithms (that remove buildings and trees) can affect the recorded elevation in a particular location. For the purposes of this study, the horizontal accuracy cannot be assumed to be greater than that of a standard USGS 7.5-minute quadrangle map, or a scale of 1:24,000**.**

[5] Light Imaging Detection and Ranging

North Central Florida Regional Planning Council

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