Hurricane Charley SLOSH Model Performance Report

December 2004

Comparison of Observed and SLOSH model computed storm surge for hurricane Charley (2004) in Southwest Florida

Under an OHS/FEMA requirement, post hurricane Charley high water mark surveys were conducted in Southwest Florida and a report was prepared (URS Group, Inc., Nov. 4 2004). The survey teams were instructed to obtain as many coastal high water marks as possible. These marks include “still water marks” inside of structures which generally reflect the storm tide elevation without the effect of waves and “outside debris lines” which generally reflect the combined effect of storm tide and wave set up and run up. Debris line elevations are generally higher than high water marks because of the added wave effects. Out of the 59 surveyed coastal high water marks the surveyors labeled 24 as inside still water marks and 35 as outside debris lines. Overall the coverage of the high water marks is very good. Several of them are located near one another to show the difference in flooding between the Gulf of Mexico shoreline sites, which often have wave effects, and those on the bay or harbor side of the island. In addition to the 59 high water marks, 3 tide gage maximums were also available and were added to give a total of 62 values. The purpose of this report is to compare these observed high water marks to the SLOSH storm surge model calculated values at the same location.

The reference datum used for the high water marks in this study is the National Geodetic Vertical Datum of 1929 or NGVD. This is where sea level was in 1929 and this was the zero elevation. Since 1929 the tide gages along the Southwest Florida coast have indicated a rise in sea level on the average of about 0.7 feet. To take the rise in sea level into account for the high water marks, the Charley SLOSH model simulation will include 0.7 feet in the initial water elevation. Also, during landfall the peak storm surge occurred approximately near the time of mean tide so that no correction was necessary for the tide elevation.

The Ft. Myers SLOSH Basin

The SLOSH model is a numerical storm surge model that computes water elevations generated by the wind and pressure forces in a tropical cyclone. Part of the model is a grid, covering the area of interest, which contains land elevations, water depths and vertical barriers, which can impede storm tide flooding. All of these are referenced to NGVD. The grid is termed a basin and given a name. The basin for Southwest Florida is called the Ft. Myers SLOSH basin. Figure 1 shows the Ft. Myers SLOSH grid. Another part of the SLOSH model allows a tropical cyclone track and intensity as input and creates a wind and pressure field, which is passed through the grid. This in turn, moves the water in the grid numerically and creates a storm surge-flooding pattern. This is termed a SLOSH model run. The history of the water elevation is saved in each grid cell and the maximum for each grid cell is displayed in what is termed the Envelope Of High Water (EOHW). The EOHW is commonly compared against high water mark observations.

Comparison of Observed High Water Marks to SLOSH Values

A SLOSH model run was made in the Ft. Myers basin using Charley track and intensity data as input. The EOHW for the SLOSH model run is shown in Figure 2a. Figure 2a also shows Charley's track and a circle representing the location of the maximum winds near landfall. The radial distance of this circle is called the Radius of Maximum Winds (RMW) and is usually given in statute miles. The RMW for Charley near landfall and during its progression through the Ft. Myers basin was approximately 7 miles. This RMW value is very small climatology speaking and a more typical value would be 20 to 25 miles. The EOHW shows the storm surge that was largely generated by the strong wind field on the right hand side of the hurricane. These strong winds created currents in the Gulf of Mexico that moved toward the shorelines and piled water up on the islands and mainland. The height of the water is given by a color code and all heights are referenced to NGVD. A large area experienced water elevations of 5 feet or greater with the SLOSH model indicating that the maximum occurred on Captiva Island and was near 8 feet. A second maximum also occurred near Ft. Myers Beach located on Estero Island and was 7 to 8 feet. This second maximum was outside the RMW but was caused because of the configuration of the coastline, which is "concave" in this region. Figure 2b is a snapshot of the SLOSH model wind field at 1910 UTC when the hurricane's center is just to the west of Sanibel Island. The wind arrows are blowing parallel to the wind. The barbs on the end of the arrow represent the wind speed in knots. A full barb is 10 knots, a half barb is 5 knots and a flag is 50 knots. The wind speed on any wind arrow is obtained by adding up the barbs and flags. For example, the wind speed over Naples is 40 knots and the wind speed at the RMW near Sanibel Island is 130 knots. Further examination of Figure 2a shows that as the hurricane moved into Charlotte Harbor and headed toward Port Charlotte it continued to generate storm surges but at smaller heights compared to the outer coastline. The reason for these smaller heights is due to the very small horizontal size of Charley's wind field even though the maximum wind speeds are still large. Figure 2c shows the 62 high water marks. The tide gage locations are noted by a star. Figure 2c also shows Charley's track with the shaded area representing the swath of the maximum winds. The high water marks in Figure 2c will be compared to the SLOSH generated EOHW values in Figure 2a.

The 62 pairs of values were subtracted from each other (i.e. SLOSH minus observed) and a bar graph of the differences was created and is shown in Figure 3. The error characteristics are indicated in the legend. Sixty-six (66) percent of the differences fall between plus 1.6 to minus 1.6 feet (plus or minus one standard deviation) while 97 percent are in the range plus 3.2 to minus 3.2 feet. The above comparison was done even though the SLOSH model does not compute wave effects and is the reason that Figure 3 has the secondary maximum near minus 2.0 feet. All of the high water marks were re-examined and wave affected high water marks were removed. This process is somewhat subjective because some of the marks that are tagged as having a wave effect in the report mentioned above are, in fact, approximately representative of the storm surge. In addition, the 7 values in Figure 3 that are greater than 1.6 feet represent locations where debris lines were

noted but were likely created after the storm tide maximum occurred and the water was receding when they were created. (i.e. the water was higher at this location than the mark indicated). The results are shown in Figure 4. The number of pairs has decreased to 41. Obviously, the results improve dramatically without the wave infected high water marks. Both Figures 3 and 4 are similar to other case studies on other individual hurricanes where the SLOSH model results were compared to observed high water marks.

Comparison of Tide Gage and SLOSH Storm Surge Hydrographs

Hydrographic records from 3 tide gages in the region of Charley=s impact were obtained. Observed storm surge hydrographs were created from the gages and these were compared to the SLOSH model-generated storm surge hydrographs for the same location based upon hurricane Charley input parameters. Figure 5 shows the U.S. Geological Survey tide gage storm surge hydrograph. The gage is located near Horseshoe Keys in Estero Bay, Florida. Also shown in the figure is the SLOSH model storm surge hydrograph for the same location. At this particular site the SLOSH model produces a maximum that is about 1 foot higher then observed and is approximately one hour late. Figure 6 is similar to figure 5 and shows the National Ocean Service's tide gage at Ft. Myers. At this location the SLOSH model does an excellent job in capturing the rate of rise of the storm surge and the maximum but does not decrease as fast as the observed. The last tide gage is located further up the Caloosahatchee River at the Franklin Locks. The SLOSH model storm surge maximum at this location is 3.2 feet compared to an observed maximum of 3.6 feet.

Conclusions

For hurricane Charley (2004), comparison of 62 observed high water marks in Southwest Florida yielded typical storm surge model error characteristics, with differences between the observed high water marks and the SLOSH generated values showing that 66% of the values fall between plus 1.6 to minus 1.6 feet and 97% are within plus 3.2 to minus 3.2 feet. Eliminating all observations that are greater than one-standard deviation, which include many wave-infected marks, gave much better results.

Comparison of the observed storm surge hydrographs at Estero Bay, Ft. Myers and Franklin Locks to the SLOSH model calculated storm surge hydrographs showed reasonable results.

Recommendations

Based upon the above results it is recommended that the following is done:

1. The SLOSH basin for Ft. Myers is reconfigured with a finer mesh of grid cells and that the latest measured water depths and land elevations are used to do this. If possible, ground controlled LIDAR data should be utilized if available.

2. A series of hypothetical hurricanes, based upon hurricane climatology, are run using the new Ft. Myers SLOSH basin to determine the hurricane storm tide flood plain. Also, small compact hurricanes, similar to hurricane Charley, should be included in the hypothetical runs.

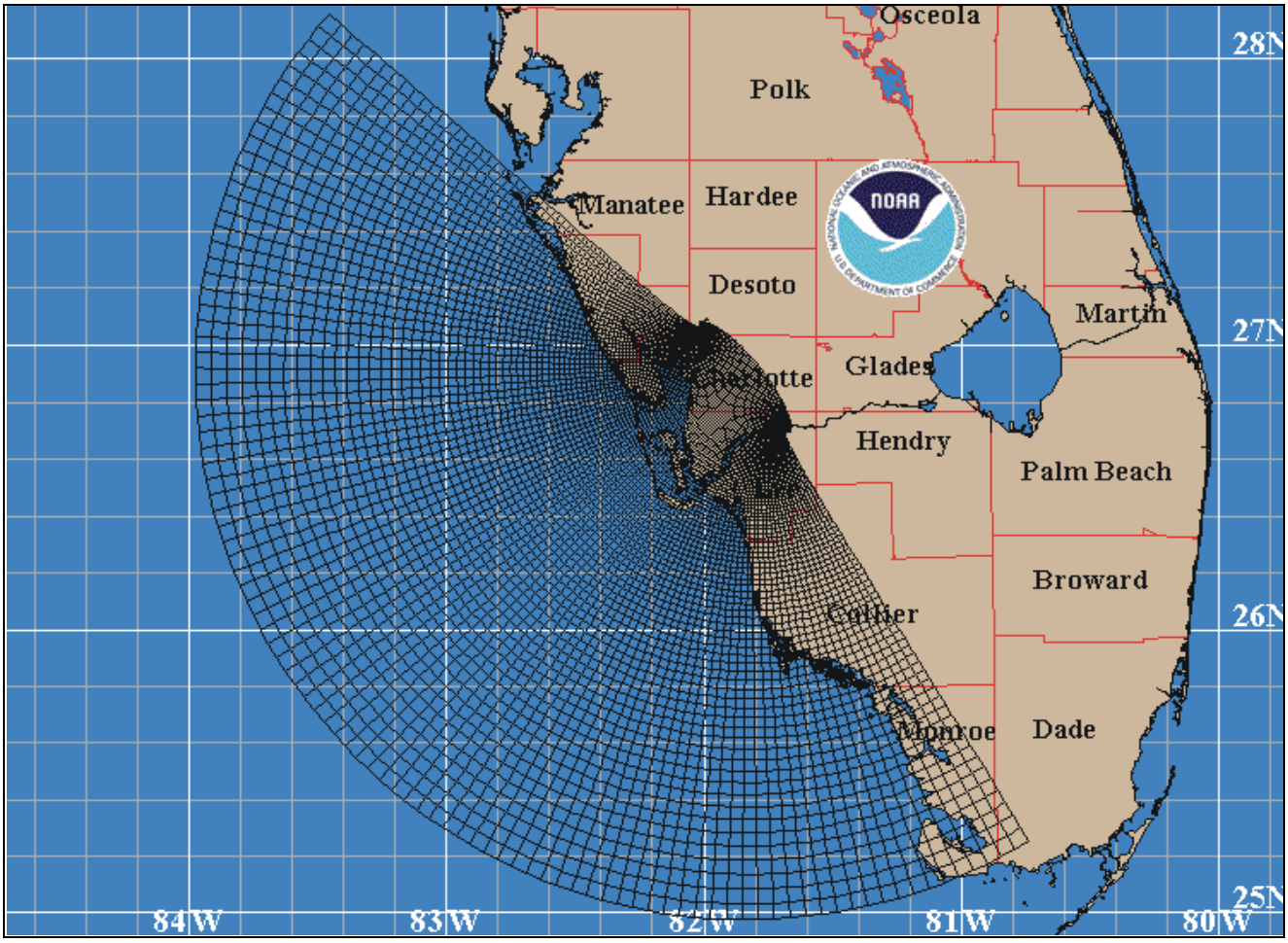

Figure 1. Ft. Myers SLOSH grid.

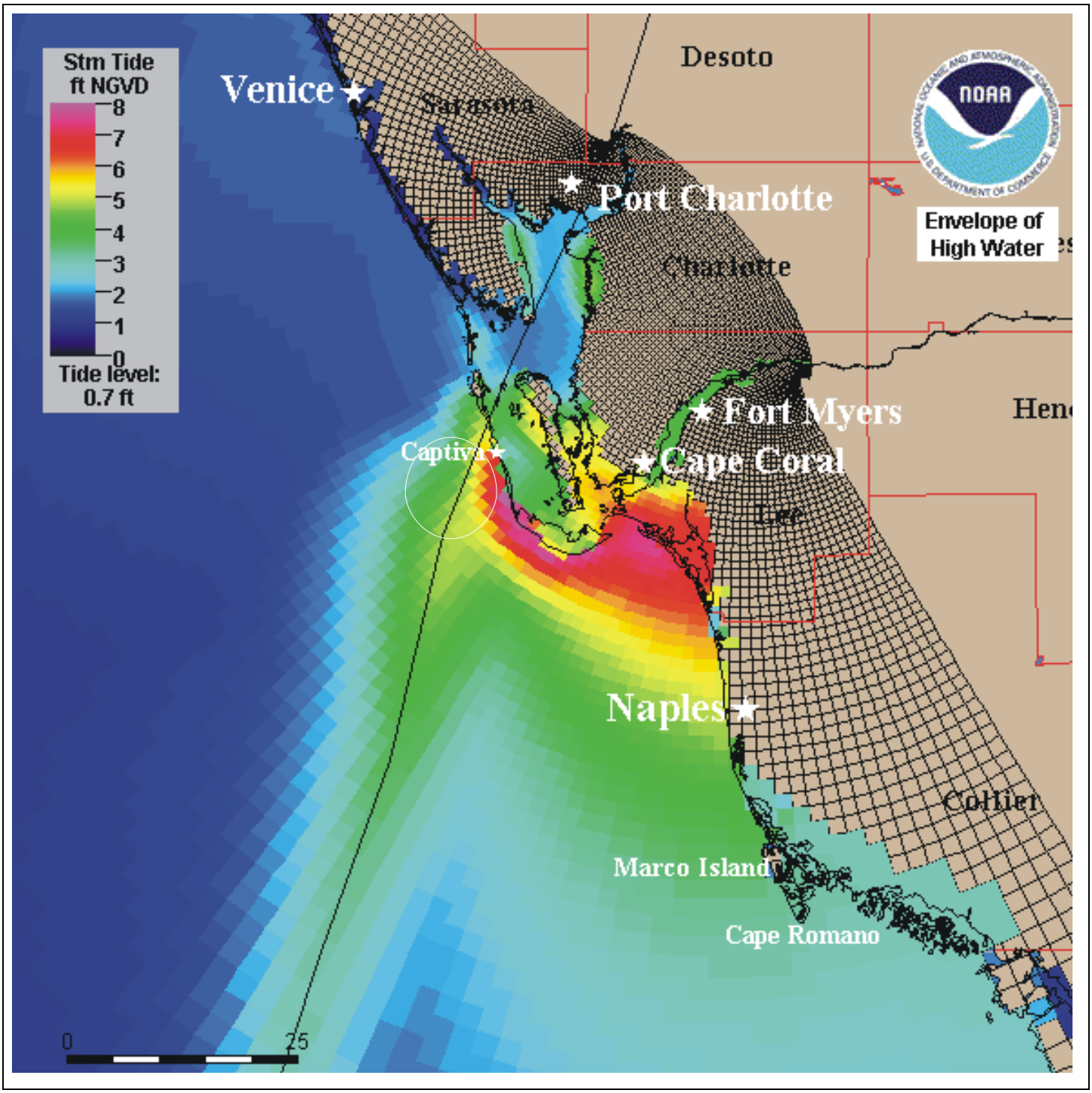

Figure 2a. SLOSH model Envelope of High Water for Hurricane Charley (2004)

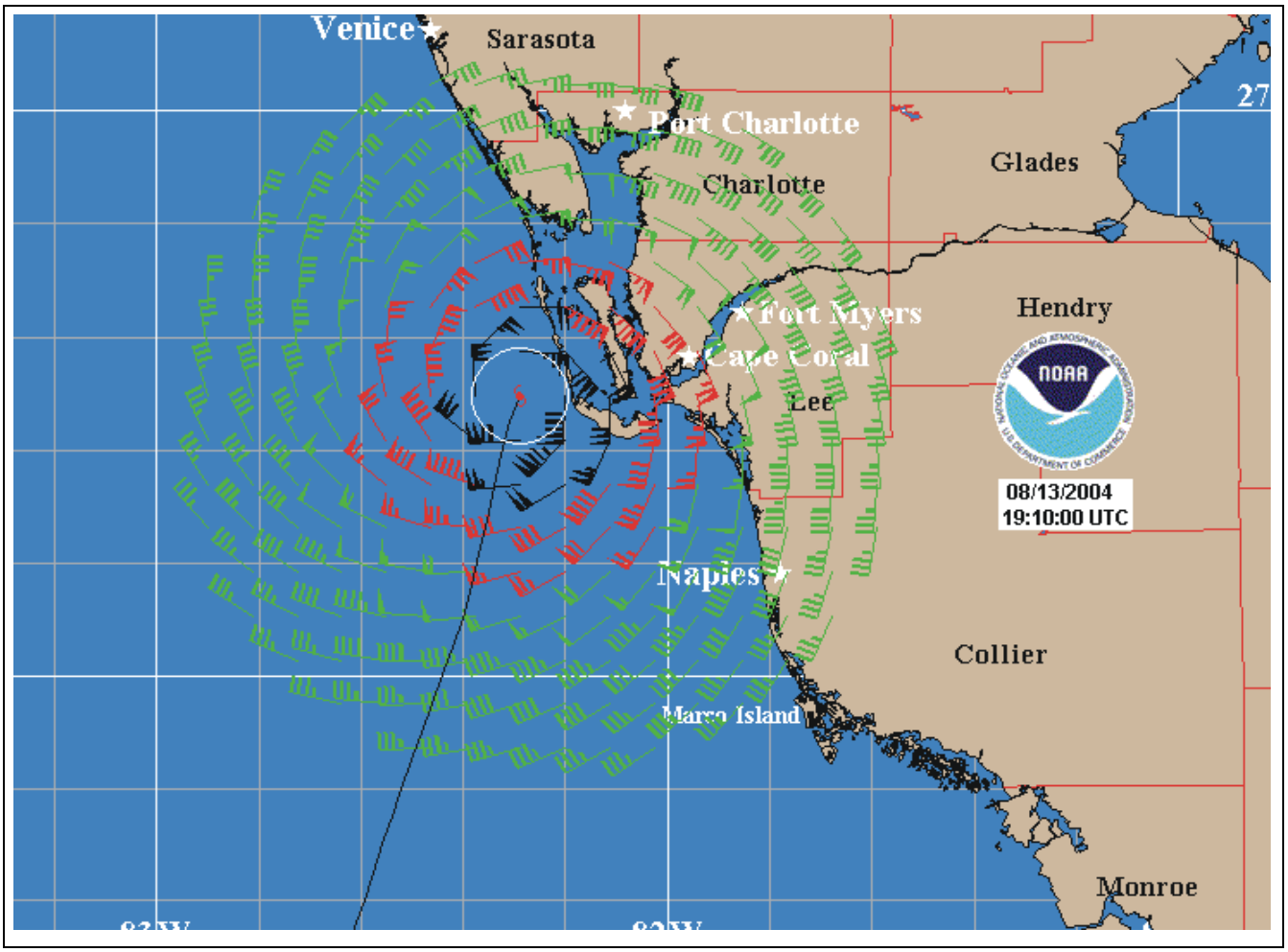

Figure 2b. SLOSH model surface wind field at 1910 UTC.

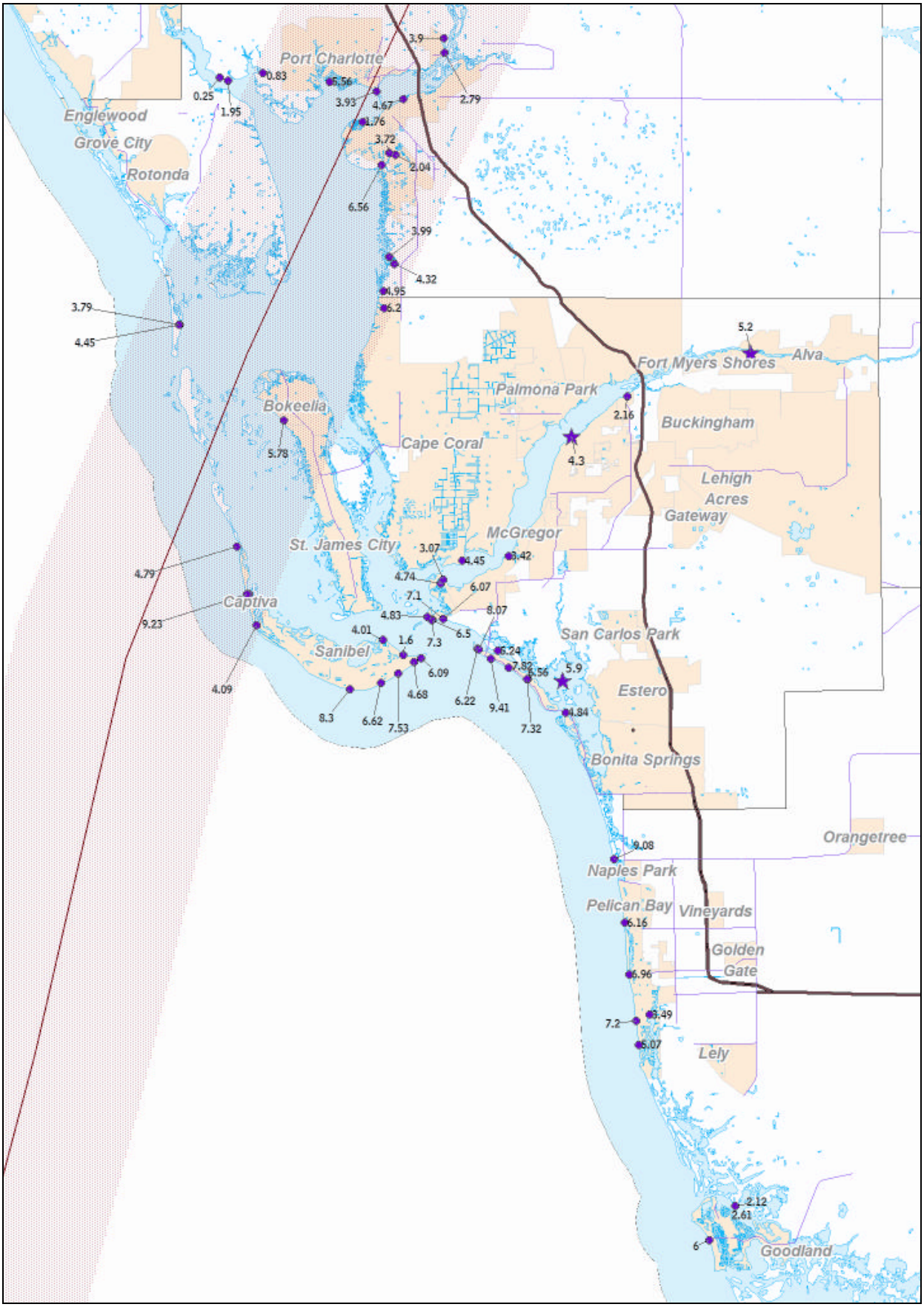

Figure 2c. Coastal high water marks obtained for Hurricane Charley (2004). Elevations in feet above NGVD. Red line is Charley's track and shaded area represents the swath of the 7 st. mi. RMW.

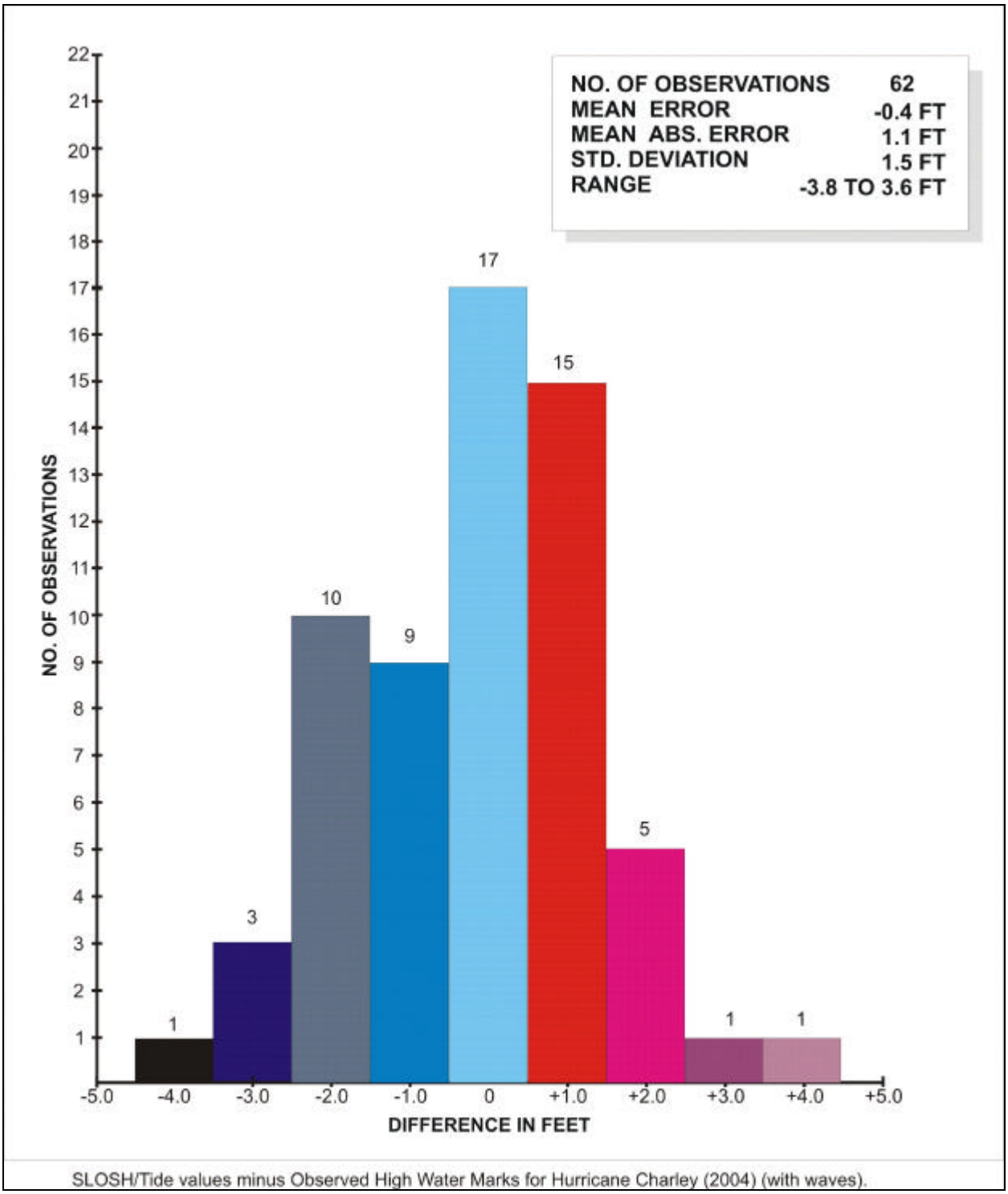

Figure 3. SLOSH/Tide values minus Observed High Water Marks for Hurricane Charley (2004) (with waves).

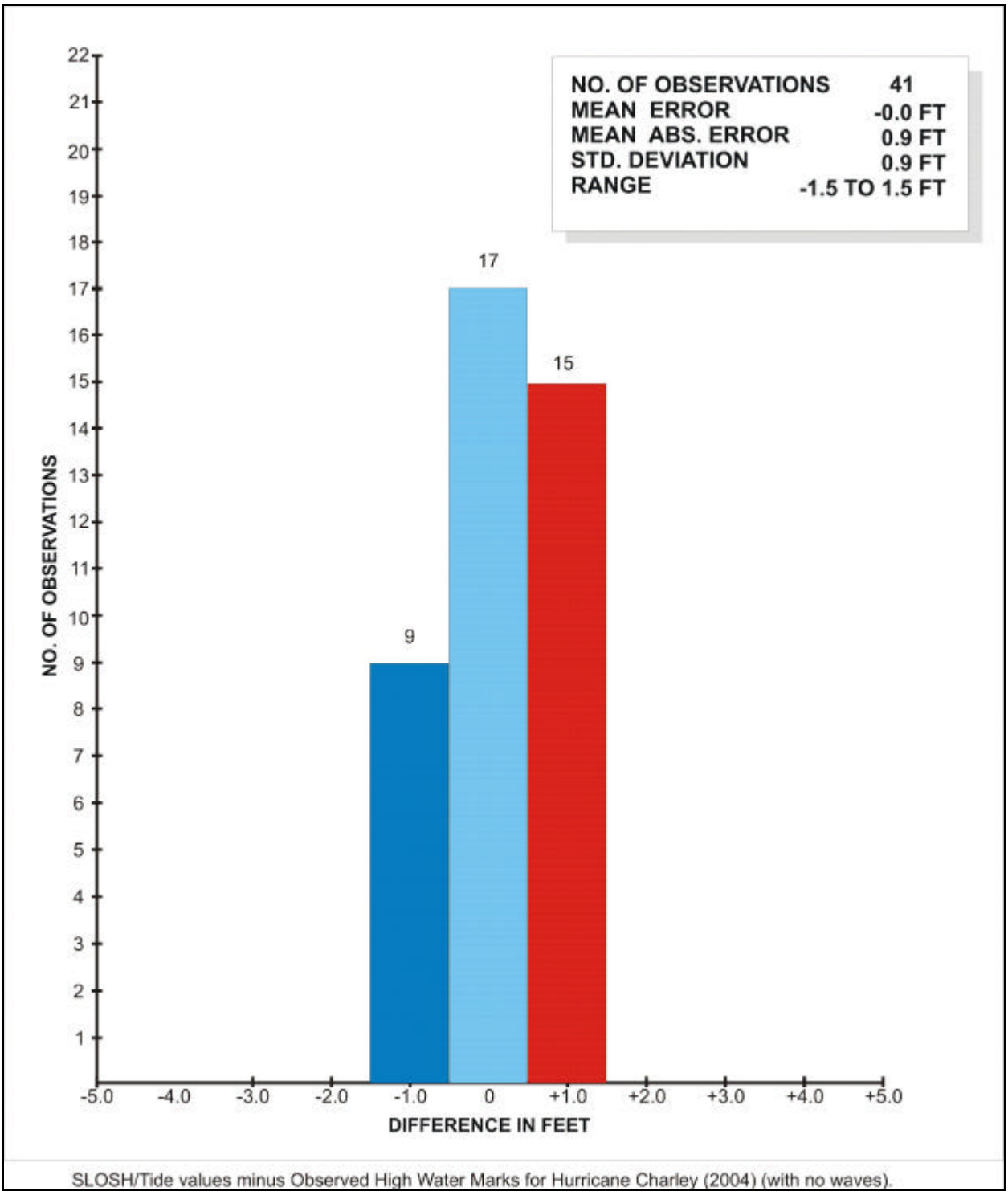

Figure 4. SLOSH/Tide values minus Observed High Water Marks for Hurricane Charley (2004) (with no waves).

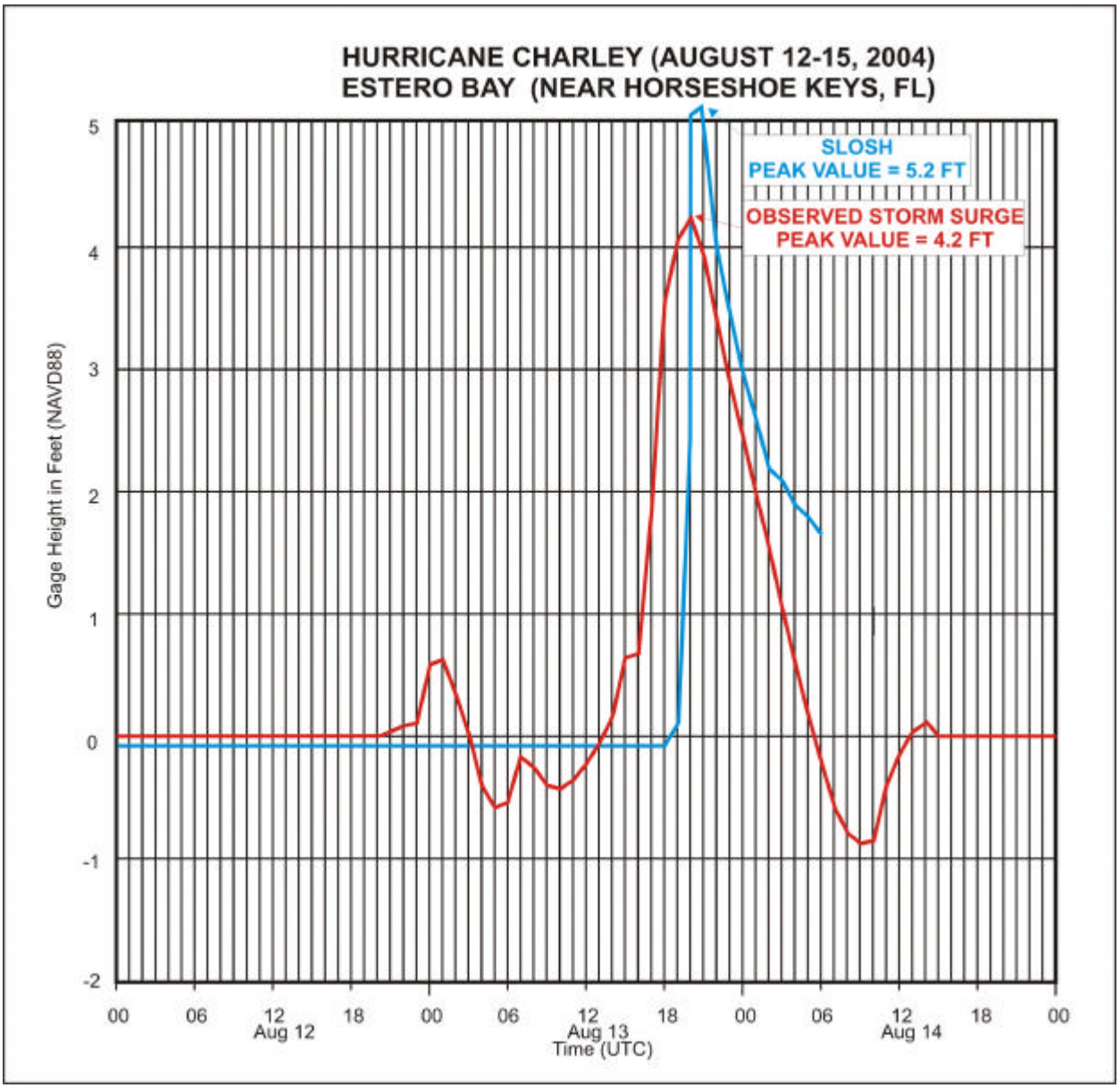

Figure 5. Comparison of Observed and SLOSH calculated storm surge hydrographs for Hurricane Charley (August 12-15, 2004) Estero Bay (Near Horseshoe Keys, Fl)

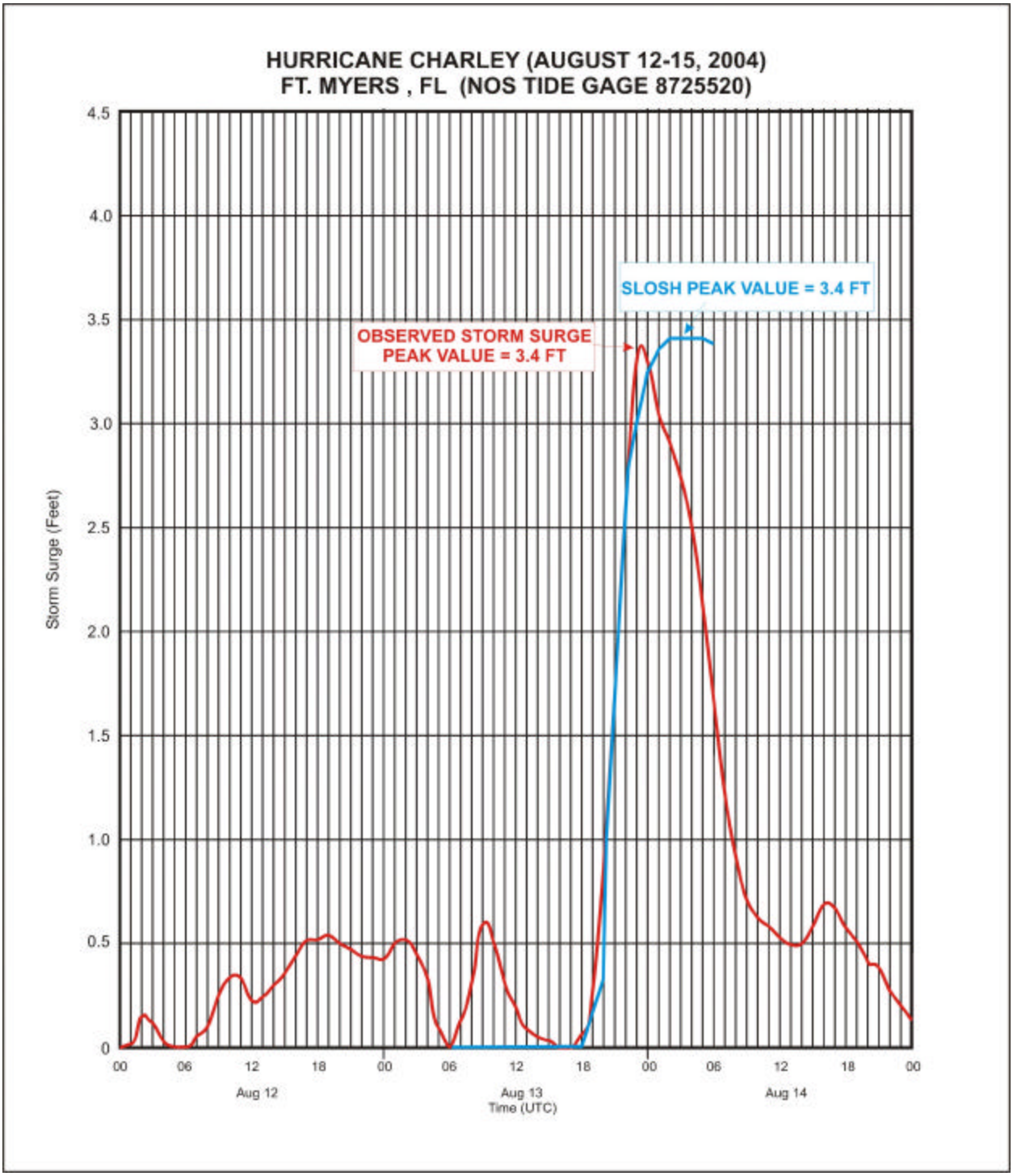

Figure 6. Comparison of Observed and SLOSH calculated storm surge hydrographs for Hurricane Charley (August 12-15, 2004) Ft. Myers, FL