# Comparison of Observed and SLOSH model computed storm surge for hurricane Jeanne (2004) on the Florida Treasure Coast

September 2005

Although OHS/FEMA had a requirement to conduct a post hurricane Jeanne high water mark survey on the Florida Treasure Coast, the agency was responding to three previous hurricane landfalls and resources were exhausted. Therefore, only two tide gauge observations were available for comparison to the SLOSH model for this hurricane. One, an NOS tide gauge, is located on the Trident Pier near Port Canaveral, Florida. The second is a "private" gauge, maintained by the firm Hazen and Sawyer. The gauge is installed at the Bear Point Mitigation site, on the east side of the Intra Coastal Waterway (ICW) about ten miles south of Fort Pierce, FL. Reference to these tide gauges was made in a previous report on hurricane Frances which passed through the same area in early September, 2004. The purpose of this report is to compare the observed storm surge hydrograph at both sites to the SLOSH storm surge model calculated hydrograph at the same locations. After the comparison was completed an additional SLOSH model run was made relative to NGVD (see next paragraph), using the prevailing tide elevation at the time of hurricane landfall and a pre-storm water elevation that existed prior to landfall. The maximum SLOSH value for this run was compared to the gauge maxima. This comparison will determine the confidence in the other SLOSH generated values, so that some inferences can be made about the maximum water elevations that occurred south of the Trident Pier.

Because only two data points were available, one on the outer coast and one in the ICW, two "final" SLOSH computations were made. The elevations of topography and depths used in the SLOSH model are referenced to the National Geodetic Vertical Datum of 1929 or NGVD29. NGVD29 is defined as the mean sea-level of 1929 and this was the "zero" elevation in the SLOSH model. Since the establishment of this datum sea level has risen about 0.25 feet in the area. To take the rise in sea-level into account the output of the Jeanne SLOSH model simulations will include an adjustment of 0.25 feet. Before the arrival of Jeanne the coastal water elevations along the east coast of Florida were an additional 1.0 foot above normal, perhaps as a result of hurricane Frances which affected the area earlier in the month. During landfall the peak storm surge at Trident Pier occurred near the time of high tide, so that an additional 1.5 feet of water elevation will be necessary to correct for the tide at that site. Thus the total water elevation used to initiate the SLOSH model simulation at Trident Pier was 2.75 feet.

For the Bear Point Mitigation site the final SLOSH model run was initialized at 0.0 ft. water level. It is difficult to know for certain what the pre-storm anomaly in the ICW was and/or how the water level might have varied from the outer coast due to inland drainage and pumping. During landfall the peak storm surge occurred at Bear Point when the tide was approximately +0.6 feet.

## THE FLORIDA "TREASURE COAST" SLOSH BASINS

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 basins covering the Florida Treasure Coast are called Cape Canaveral and Palm

Beach. Figures 1a and 1b show the Cape Canaveral and Palm Beach SLOSH basins and their respective grids. Where the grids overlap, the one with the smaller grid cells (i.e. finer resolution) is usually used to compare against observed data. In the present circumstance it was decided to use the expanded Palm Beach basin, PB2, as both observation sites could be calculated and displayed in the same basin. The SLOSH model uses as input a tropical cyclone track and intensity and creates a wind and pressure field which is passed through the grid. This, in turn, numerically moves the water in the grid and creates a storm surge flooding pattern. This is termed a SLOSH model run. The time 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.

Shown in Figure 2 are Jeanne's track and a circle representing the location of the maximum winds near the time of 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 Jeanne near landfall and during its progression through the Palm Beach basin was approximately 35 statute miles. 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, in Figure 3, the wind speed over Broward County is 70 knots and the wind speed at the RMW near Vero Beach is 95 knots.

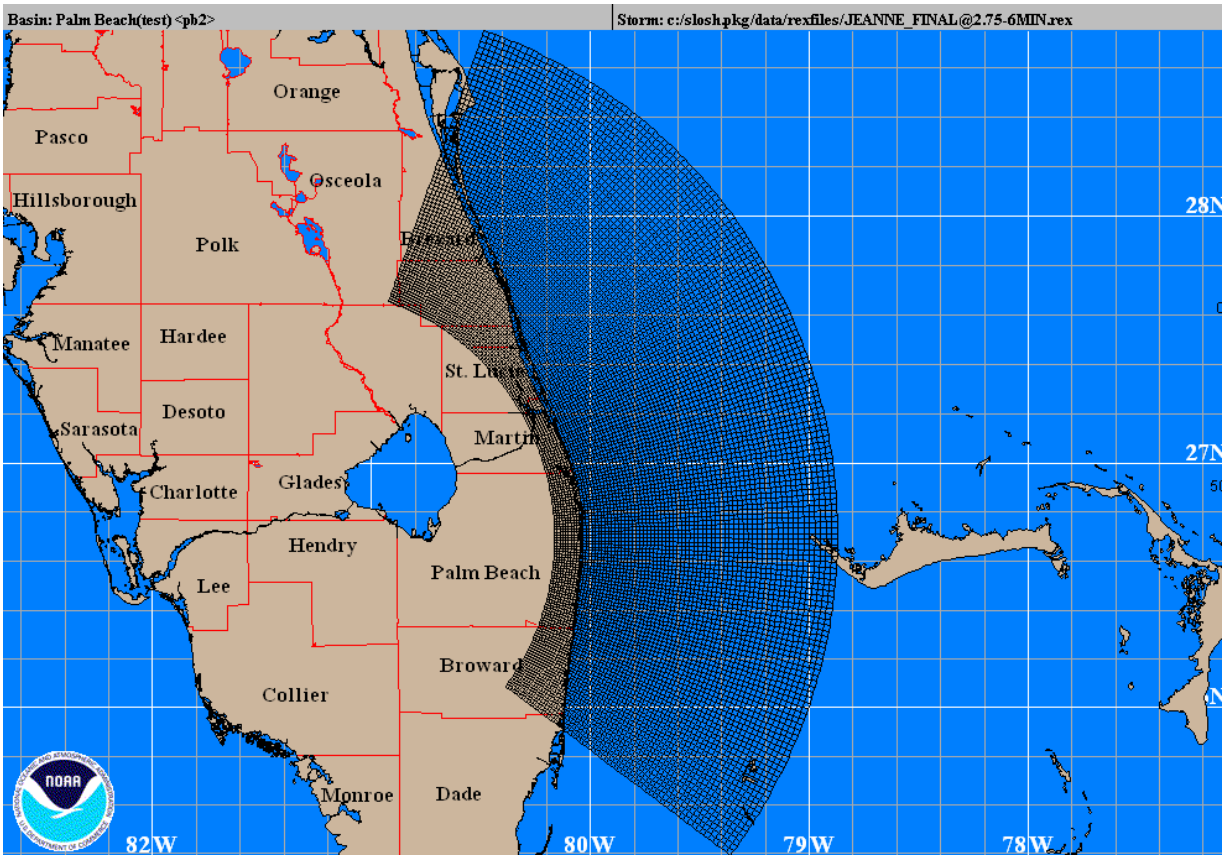

Figure 1a. Palm Beach SLOSH domain.

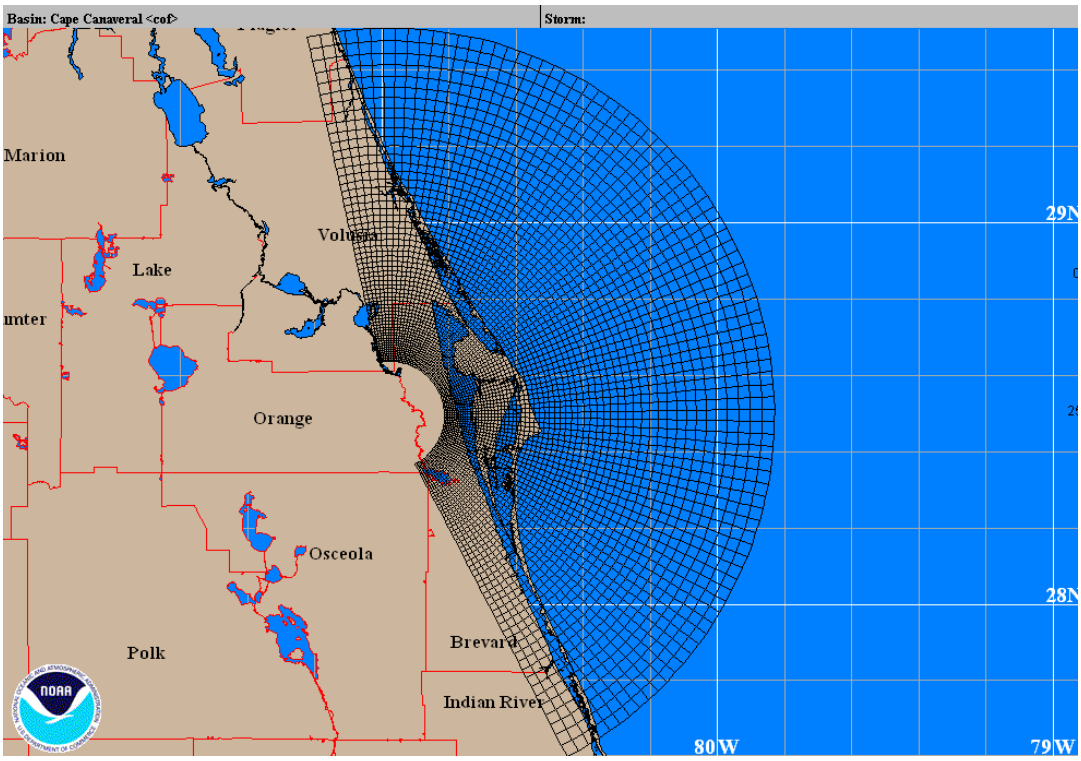


Figure 1b. Cape Canaveral SLOSH domain.

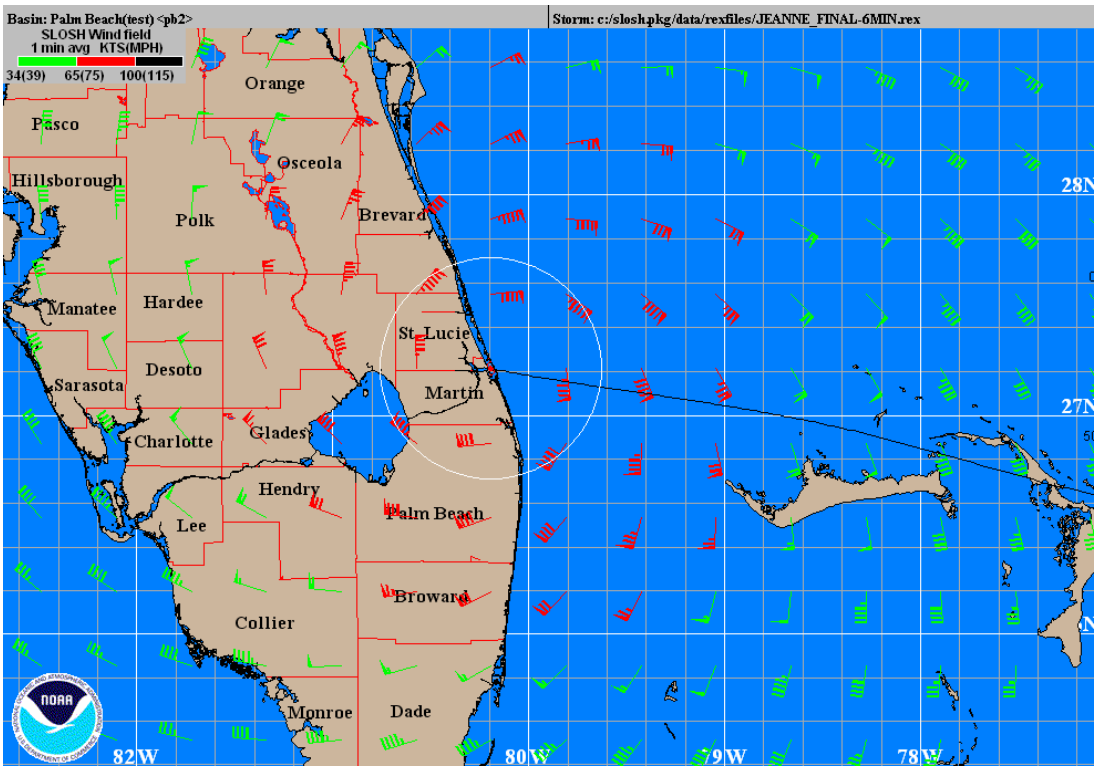


Figure 2. Hurricane Jeanne winds at landfall.

**Comparison of the Trident Pier and Bear Point Observed High Water Marks to SLOSH Values**

SLOSH model runs were made in the Palm Beach basin (PB2) using best-track Jeanne track and intensity data as input. The EOHW for the final best-track/intensity SLOSH model run is shown in Figure 3. The display shows a model initialization at 2.75 ft., appropriate for Trident Pier. 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 Atlantic Ocean that moved toward the shoreline and piled water up on the barrier islands and mainland. The height of the water, referenced to NGVD, is given by a color code. A large area of ocean shoreline experienced water elevations of 8 feet or greater. The SLOSH model calculated that the maximum occurred near Vero Beach, Florida and was near 10 feet.

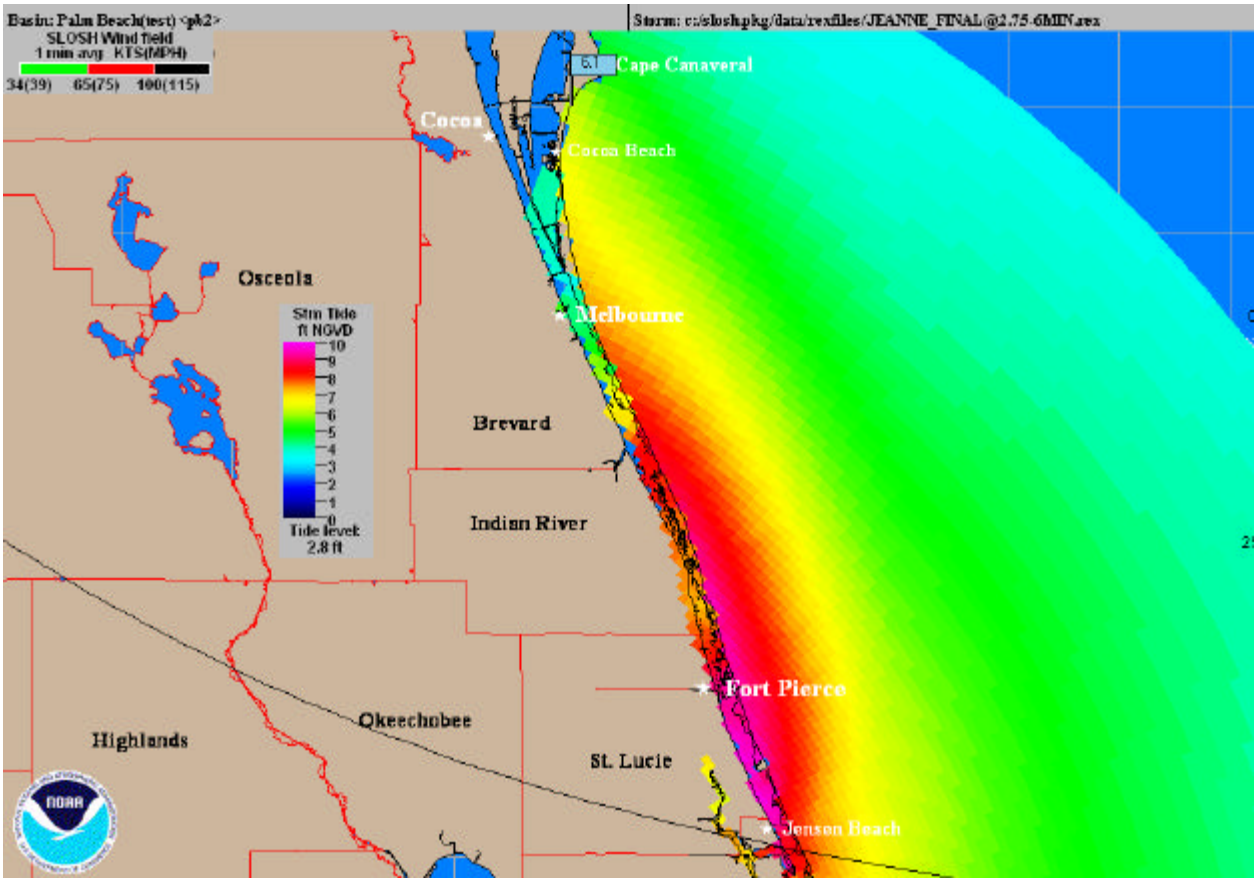


Figure 3. EOHW at Trident Pier, SLOSH initialized at +2.75 ft.

Further examination of Figure 3 shows that the hurricane pushed water into the Indian River and some high water elevations occurred there. The Trident Pier tide gauge location is noted by a flag showing the EOHW. The observed high water mark at the Trident Pier was compared to the SLOSH generated high water obtained from the output EOHW. The comparison gives a SLOSH value of +6.1 feet NGVD versus an observed value of +6.5 feet NGVD.

As previously noted, for the comparison of Bear Point Mitigation site gauge with SLOSH the model run was initialized at 0.0 ft. Figure 4 shows +4.4 ft. NGVD at Bear Point and +3.4 ft. NGVD at Trident Pier. The pre-storm anomaly of +1.0 ft. that was used for Trident Pier was also used for Bear Point. The MTL adjustment for Bear Point is +0.36 ft. The calculated tide at Bear Point was +0.6 ft. The total adjustment for Bear Point therefore was +1.96 feet, yielding a calculated total elevation of +6.3 ft NGVD. The observed elevation at the Bear Point gauge was +6.5 ft. NGVD. A check on the utility of this technique can be had by adding the Trident Pier adjustments to the 0.0 ft. initialized SLOSH run at Trident Pier. The result is +2.75 plus (computed) +3.4 ft., total +6.2 ft. NGVD versus an observed height of +6.5 ft. NGVD. As noted above, initiation of the model at +2.75 produced a very similar result of +6.1 at Trident Pier.

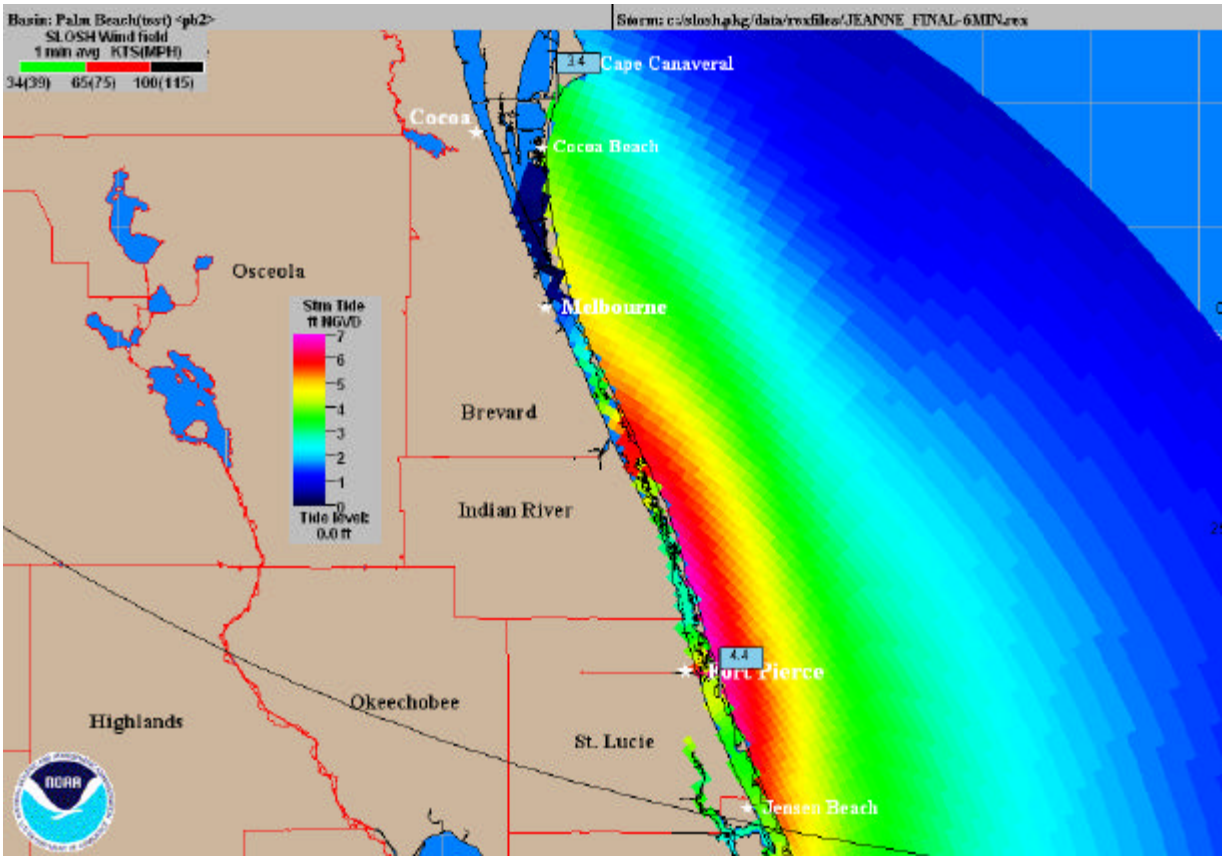


Figure 4. EOHW, SLOSH initialized at 0.0 ft.

**Comparison of the Trident Pier and Bear Point Gauges with SLOSH Storm Surge Hydrographs**

The hydrographic records at the Trident Pier and Bear Point tide gauges were obtained and were compared to the SLOSH model-generated storm surge hydrographs for the same locations using hurricane Jeanne input parameters. Figures 5 and 6 show the comparisons. The comparison is excellent at Trident Pier. The elevation is very good at Bear Point though the phasing is off by ~3-1/2 hours. This is not an unusual finding when non-coastal observations are compared with SLOSH calculations.

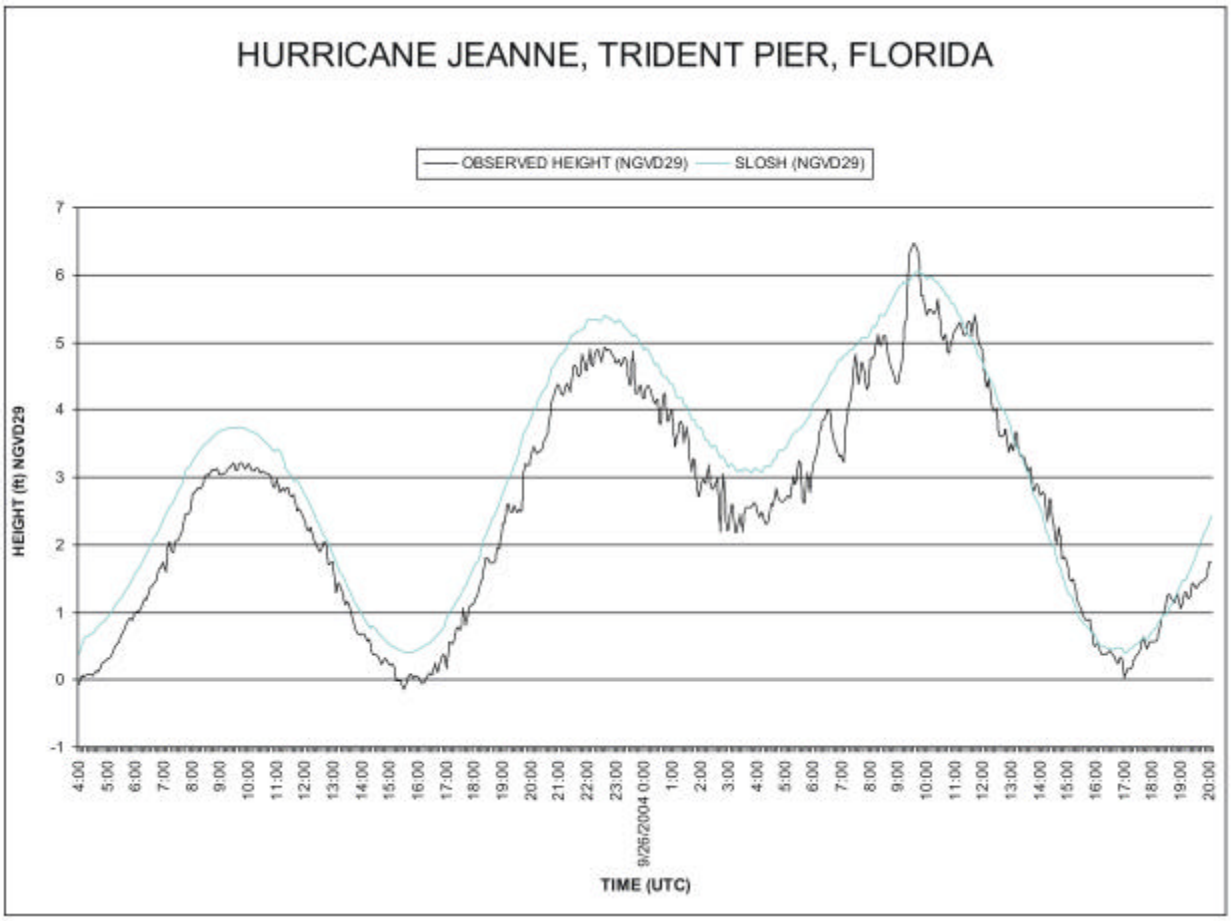


Figure 5. Observed vs. SLOSH hydrographs, Trident Pier.

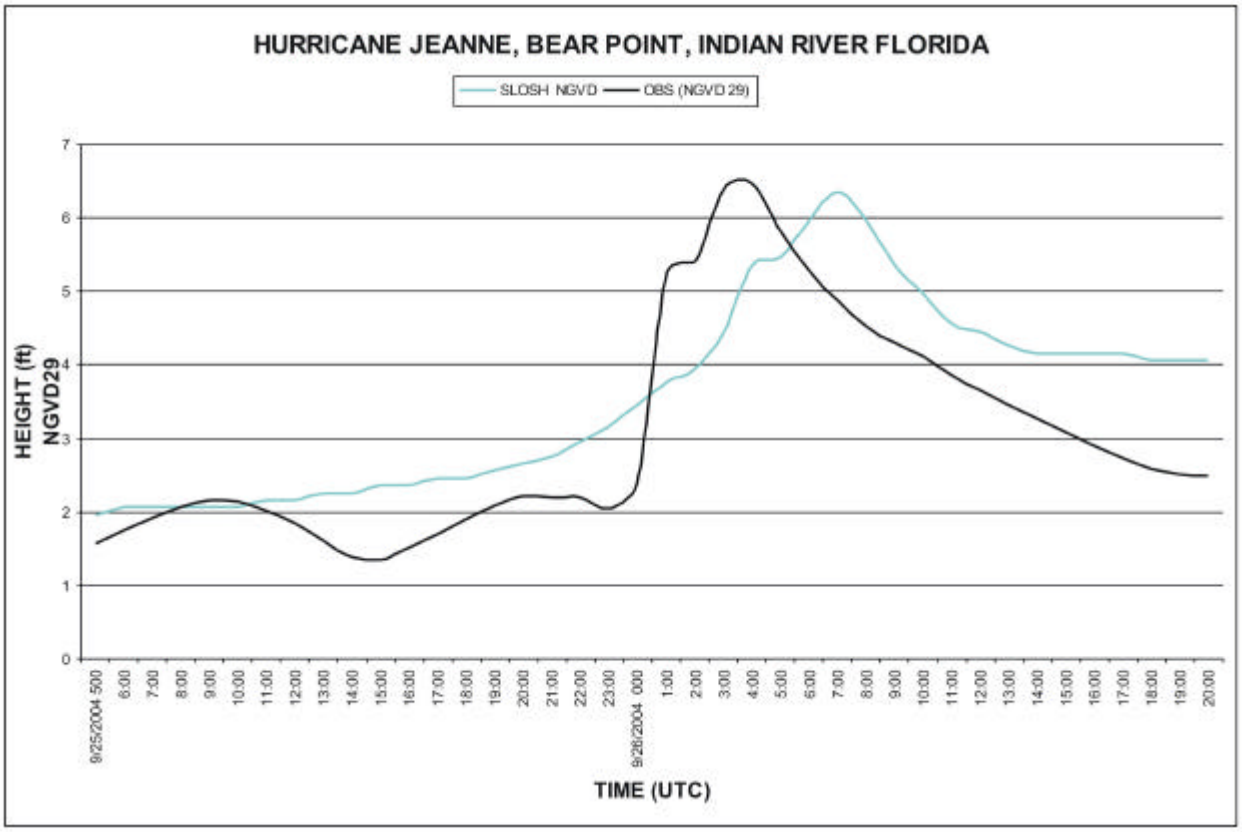


Figure 6. Observed vs SLOSH hydrographs, Bear Point

## Conclusions

For hurricane Jeanne (2004) the observed and SLOSH calculated high water mark comparison was good at the Trident Pier and Bear Point locations.

Likewise, a comparison of the observed storm surge hydrographs from the Trident Pier and Bear Point to the SLOSH model calculated storm surge hydrographs showed reasonable results.

## Recommendations

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

1. The SLOSH basins for Palm Beach (and the contiguous Cape Canaveral basin) are reconfigured with a finer mesh of grid cells and that the latest measured water depths and land elevations are used to do this. Ground controlled LIDAR data should be utilized if available.

2. A series of hypothetical hurricanes, based upon hurricane climatology, are run using the new Palm Beach and Cape Canaveral SLOSH basins to determine the hurricane storm tide flood plain.

We thank Hazen and Sawyer, Inc. for the provision of Bear Point tide gauge data.