Analysis of Storm Surge Measured at Water Level Stations from Hurricanes Charley, Frances, Ivan & Jeanne

[1]Gerald T. Hovis

2004 HURRICANE SEASON AND STORM SURGE

In May forecasters with the National Oceanic Atmospheric Administration (NOAA) predicted an above normal activity for the 2004 hurricane season citing warm Atlantic sea surface temperatures and lower wind shear and surface pressure (NOAA 2004). In August this forecast was downgraded slightly citing weak El Nino conditions increasing Caribbean and Atlantic wind shear weakening hurricane formation. The season ended up with 16 tropical depressions, 15 named storms, 9 hurricanes, and six major hurricanes, placing it the third most active year behind only 1950 and 1995 (Bell et al. 2004). The most significant storms were Hurricanes Charley, Frances, Ivan, and Jeanne, which all made landfall in the state of Florida. This was the first time four hurricanes have hit one state in a season since four hit Texas in 1886. (Bell et al. 2004). Throughout the 2004 season NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) recorded water levels and associated storm surge along the East and Gulf coasts. The primary physical components of storm surge are 1) water level elevation due to wind stress produced by a storm, manifested as water pushed toward the shore, and 2) water elevation resulting from diminished atmospheric pressure. Complex hydrodynamic phenomena such as tidal current interaction with bathymetry and topography, wave action, and seiche may also be present during a major coastal storm, and can be additional components of storm surge (Hovis 2003). Storm surge, for CO-OPS mission purposes, is computed simply as *the difference between the observed water level and the predicted tide level.* During the 2004 season recorded surge levels were highest during hurricane IVAN, however, each storm produced surges of varying degrees and occurances throughout Florida.

MONITORING WATER LEVELS

The National Ocean Service's (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) collects and distributes observations and predictions of water levels and currents. The Center supports NOS' Strategic Plan mission requirements, of providing operational oceanographic data/products and other Strategic Plan themes such as facilitating the National Weather Service (NWS) to meet its storm warning responsibilities. These obligations are accomplished through the operation of the National Water Level Observation Network (NWLON), and a national network of Physical Oceanographic Real-Time Systems (PORTS) in major U.S. harbors.

[1]NOAA, National Ocean Service, CO-OPS, Products and Services, N/OPS3 1305 East-West Highway, Silver Spring, MD 20910 *gerald.hovis@noaa.gov*

The National Water Level Observation Network is composed of approximately 175 long -term, stations distributed along the U.S. coast and on islands in the Atlantic and Pacific Oceans. Data from NWLON stations are used to support navigational safety, coastal forecasting, surveying and mapping, coastal engineering, marine boundary determination, monitoring of seasonal and long-term sea levels, and storm warning systems. CO-OPS also operates PORTS®, which currently has systems active in twelve U.S. ports providing real-time water level data to users to ensure safe navigation.

The Next Generation Water Level Measurement System (NGWLMS) installed at most NWLON and PORTS® stations acquires, stores, and transmits water level, meteorological, and other environmental data. The instruments typically installed at NWLON and PORTS® stations are acoustic water level sensors recording a 6-minute water level values derived from the mean of 181 one-second measurements. During times of severe storms, these gauges operate in a special mode to provide data every 18 minutes for distribution to the NWS Advanced Weather Interactive Processing System (AWIPS) network. The National Hurricane Center (NHC) reports on tropical formation of hurricanes are monitored and utilized to determine when, and for which, stations to trigger the special reporting mode capability. Observed data are then compared to the predicted tide to show storm surge elevations during storm events. State and federal emergency management agencies utilize this data to help formulate evacuation strategies.

DISSEMINATION OF DATA VIA CO-OPS WEBSITE

The data obtained from NWLON and PORTS® stations is also used to support CO-OPS Tides Online (TOL) website. The Tides Online website provides users with immediate graphical and tabular water level and meteorological data from NOS water level stations located along the projected path of severe storms such as hurricanes. For those stations activated, manually or automatically, for storm surge transmission rates, the Tides Online product also isolates their selection for convenient interactive display. Tides Online can be accessed through the CO-OPS web page or by connecting to **tidesonline.nos.noaa.gov**.

Recognizing the need for rapid dissemination of concise water level and storm surge information CO-OPS began distributing a **Storm Surge QUICKLOOK** product during the 2004 hurricane season (Figure 1). CO-OPS scientists monitor NHC storm forecast advisories and post a **Storm Surge QUICKLOOK** that can be accessed through the main CO-OPS website **http://www.co-ops.nos.noaa.gov/** or through the TOL website. This product provides users with a snapshot of water level and storm surge conditions at locations being impacted by storm events. The **QUICKLOOK** contains a summary statement of current water level conditions, a hurricane track with CO-OPS water level stations, and a selection of hydrographs that best characterize water level and storm surge conditions. The **QUICKLOOK** is updated at 1200 and 1800 EDT during hurricane events and adjusted as storm conditions warrant.

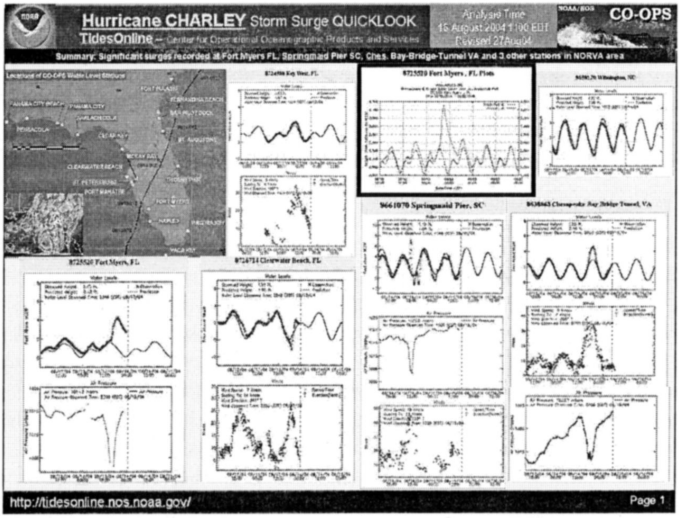

Figure 1. Example of Storm Surge QUICKLOOK during Hurricane CHARLIE.

LANDFALL LOCATIONS AND ADJACENT CO-OPS WATER LEVEL STATIONS FOR HURRICANES CHARLIE, FRANCES, IVAN AND JEANNE

CO-OPS personnel actively maintained and monitored water level stations which provided valuable data from 66 water level stations during the 2004 passing of Hurricanes CHARLIE, FRANCES, IVAN and JEANNE (Figure 2). Hurricane CHARLIE made landfall near Cayo Costa, FL (near Ft Meyers) around 1945 UTC 13 August as a Category 4 hurricane with maximum sustained winds near 130 kts. CHARLIE passed over Central Florida reentered the Atlantic and came ashore again near cape Romain, SC at about 1400 UTC 14 August with maximum sustained winds of about 70 kts. During its passage CO-OPS obtained water level data from 19 stations from Ft. Meyers, FL north to Kiptopeke, VA. Hurricane FRANCES made landfall over the southern end of Hutchinson Island, FL near Stuart, FL at 0430 UTC 5 September as a Category 2 hurricane with maximum sustained winds of about 90 kts. FRANCES passed over Central Florida entered the Gulf and came ashore again in Florida's panhandle near St Marks at about 1800 UTC 6 September with maximum sustained winds of about 55 kts. CO-OPS obtained water level data from 18 stations from Mayport near Jacksonville, FL all around the southern tip of Florida north to Apalachicola, FL. Hurricane IVAN made landfall as a 105 kt, Category 3 hurricane at approximately 0650 UTC 16 September near Gulf Shores, AL. After traveling north through Alabama and on into the midatlantic region remnants of IVAN turned south crossed back over Florida as an extra tropical low reentered the Gulf and made landfall as a tropical depression near Cameron, LA around 0200 UTC 24 September. IVAN impacted about 30 stations from Vaca Key on Florida's southern east coast to Port Isabel in southern Texas. Hurricane JEANNE made landfall on the east coast of

Florida early on 26 September near Stuart as a Category 3 hurricane with maximum sustained winds of 105 kts. CO-OPS recorded water level data from about 19 stations from the Virgin Islands to Cedar Key, FL.

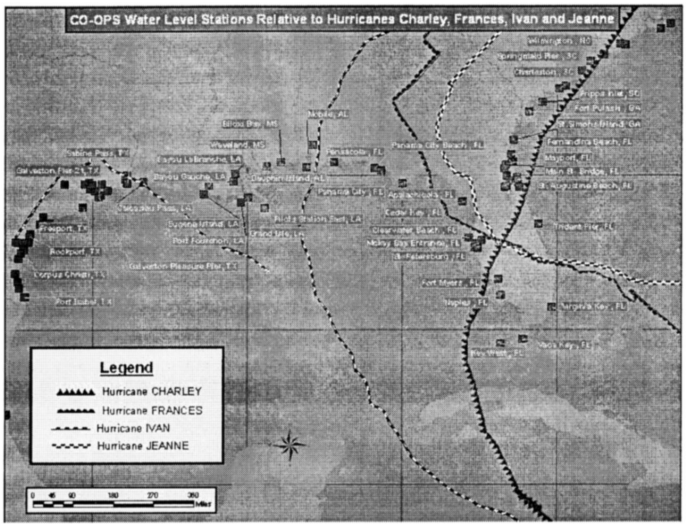

Figure 2. CO-OPS water level stations relative to hurricanes CHARLIE, FRANCES, IVAN and JEANNE.

SUMMARY OF MAXIMUM WATER LEVELS AND STORM SURGE DURING HURRICANES CHARLIE, FRANCES, IVAN AND JEANNE

HURRICANE CHARLIE

The water level stations located along the coast of Georgia, South Carolina and North Carolina recorded the highest water levels during hurricane CHARLIE's second landfall. This was after it had already made landfall near Ft. Meyers and crossed central Florida. Sunset Beach, NC recorded the highest observed water level of 2.498 m (Table 1). Fort Pulaski, GA, Springmaid Pier, SC, and St. Simons, GA recorded the next three highest water levels with 2.297 m, 2.193 m, and 2.175 m respectively. Near Cayo Costa where CHARLIE made its initial landfall the Ft. Meyers station recorded a water level of 1.309 m. Sunset Beach, NC recorded the highest storm surge at 2.336 m (Table 2 and Figure 3). The Ft Meyers station, where CHARLIE initially made landfall recorded a surge of 1.020 m which was significantly lower than Sunset Beach. In contrast, Springmaid Pier, SC and Wilmington, NC recorded the second and third highest storm surges of 1.857 m and 1.396 m, which were both higher than the storm surge recorded at Ft. Meyers. Most of the surge dissipated within one tidal cycle as can be seen by the storm surge hydrograph at Sunset Beach, NC (Figure 4).

Table 1. Maximum observed water levels during hurricane CHARLIE.

Maximum Observed Water Levels Referred to MLLW, NAVD 88 and NGVD 29					
Station ID	Station Name	Date/Time GMT	Maximum Observed Water Level Above MLLW (m)	Maximum Observed Water Level Above NAVD88 (m)	Maximum Observed Water Level Above NGVD 29(m)
8725520	Fort Meyers,FL	08-13-04 23:06	1.309	0.991	1.349
8720030	Fernandina, FL	08-17-04 02:00	1.959	0.794	NA
8670870	Fort Pulaski,GA	08-19-04 02:30	2.297	1.062	1.350
8677344	St. Simons, GA	08-17-04 01:18	2.175	0.898	NA
8665530	Charleston, SC	08-18-04 01:48	1.756	0.799	1.098
8662245	Oyster Landing, SC	08-18-04 02:24	1.598	NA	NA
8661070	Springmaid Pier, SC	08-14-04 15:30	2.193	1.231	1.532
8651370	Sunset Beach, NC	08-14-04 16:18	2.498	NA	NA
8658120	Willmington, NC	08-18-04 03:30	1.514	0.781	1.085
8656483	Beaufort, NC	08-14-04 23:36	1.197	0.564	0.857
8652587	Oregon Inlet, NC	08-14-04 23:00	0.714	0.512	0.617
8638863	Ches. Bay Bridge,VA	08-15-04 00:36	1.414	NA	NA
8651370	Duck, NC	08-17-04 00:42	1.261	0.594	0.888
8639348	Money Point, VA	08-15-04 01:06	1.495	0.938	1.185
8638610	Sewell's Point, VA	08-15-04 01:06	1.296	0.795	1.043
8636580	Windmill, VA	08-15-04 02:12	0.580	0.291	0.543
8631044	Wachapreague, VA	08-15-04 01:30	1.569	NA	NA
8637689	Yorktown , VA	08-15-04 01:24	1.161	NA	NA
8632200	Kiptopeke, VA	08-15-04 00:30	1.288	0.708	0.959

Table 2. Maximum observed storm surge during hurricane CHARLIE.

Maximum Storm Surge (Greatest Difference Between Observed and Predicted)					
Station ID	Station Name	Date/Time GMT	Observed Water Level Above MLLW(m)	Predicted Water Levels (m)	Maximum Surge (m)
8725520	Fort Meyers,FL	08-13-04 22:54	1.304	0.284	1.020
8670870	Fort Pulaski,GA	08-14-04 10:54	2.043	1.862	0.181
8677344	St. Simons, GA	08-14-04 08:12	1.11	0.75	0.36
8665530	Charleston, SC	08-14-04 13:36	1.717	1.12	0.597
8662245	Oyster Landing, SC	08-14-04 16:18	1.286	0.391	0.895
8661070	Springmaid Pier, SC	08-14-04 15:30	2.193	0.336	1.857
8659897	Sunset Beach, NC	08-14-04 16:18	2.498	0.162	2.336
8658120	Willmington, NC	08-14-04 18:54	1.483	0.087	1.396
8656483	Beaufort, NC	08-14-04 19:24	0.8	0.342	0.458
8652587	Oregon Inlet, NC	08-13-04 16:42	0.474	0.072	0.402
8638863	Ches. Bay Bridge, VA	08-15-04 00:36	1.414	0.892	0.522
8651370	Duck, NC	08-17-04 07:12	0.177	0.046	0.131
8639348	Money Point, VA	08-15-04 00:36	1.474	0.989	0.485
8638610	Sewell's Point, VA	08-15-04 00:30	1.285	0.834	0.451
8636580	Windmill, VA	08-16-04 12:54	0.431	0.266	0.165
8631044	Wachapreague, VA	08-15-04 02:48	1.39	1.09	0.3
8637689	Yorktown , VA	08-15-04 01:24	1.164	0.72	0.444
8632200	Kiptopeke, VA	08-15-04 00:30	1.288	0.909	0.379

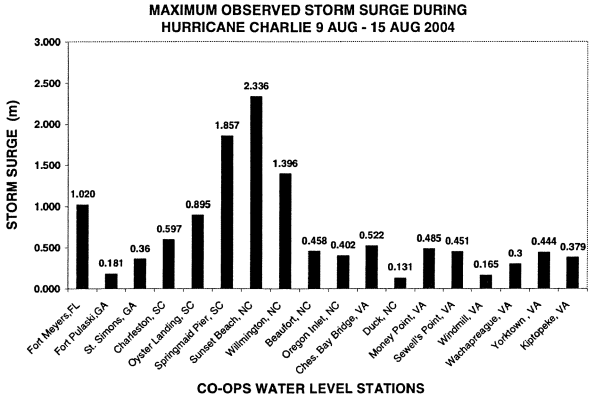

Figure 3. Maximum observed storm surge during hurricane CHARLIE.

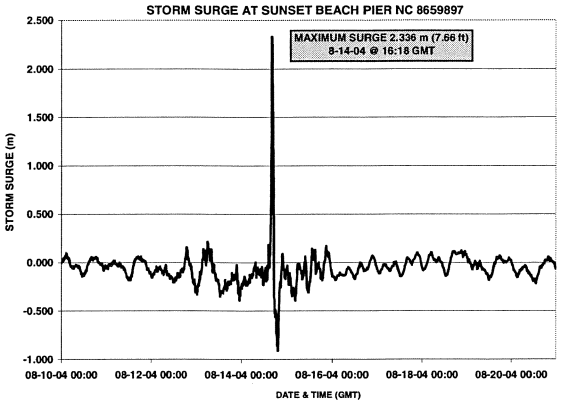

Figure 4. Storm surge at Sunset Beach, NC.

HURRICANE FRANCES

The highest observed water levels during hurricane FRANCES were recorded at Trident Pier (2.158 m), Crescent Beach (2.019 m), Cedar Key (2.014 m), and Mayport Naval Station (1.935 m) (Table 3). During the second landfall of FRANCES near St Marks, FL several stations experienced recorded levels significantly lower than astronomical predictions and then rapidly rose. Cedar Key is representative of those stations that experienced this rapid oscillation in water level (Figure 5). This rapid rise also resulted in Cedar Key recording the highest storm surge value of 1.705 m. (Table 4 and Figure 6).

Table 3. Maximum observed water levels during hurricane FRANCES.

Maximum Observed Water Levels Referred to MLLW, NAVD 88 and NGVD 29					
Station ID	Station Name	Date/Time GMT	Maximum Observed Water Level Above MLLW (m)	Maximum Observed Water Level Above NAVD88 (m)	Maximum Observed Water Level Above NGVD 29(m)
8720211	Mayport Naval , FL	09/05/04 17:48	1.935	n/a	n/a
8720218	Mayport, FL	09/05/04 17:54	1.837	n/a	n/a
8720226	Main Street Bridge, FL	09/06/04 08:18	1.373	0.957	n/a
8720357	I-295 Bridge, FL	09/06/04 08:48	1.125	n/a	n/a
8720503	Red Bay Point, FL	09/06/04 09:48	1.000	n/a	n/a
8720554	Vilano Beach, FL	09/05/04 17:30	1.835	n/a	n/a
8720625	Racy Point, FL	09/06/04 12:18	0.953	0.744	n/a
8720651	Crescent Beach, FL	09/05/04 19:36	2.019	n/a	n/a
8720757	Bings Landing, FL	09/05/04 21:48	1.276	n/a	n/a
8720767	Buffalo Bluff, FL	09/06/04 01:48	1.063	n/a	n/a
8720774	Palatka, FL	09-06-04 04:06	0.986	n/a	n/a
8721604	Trident Pier, FL	09/05/04 15:54	2.158	n/a	n/a
8725110	Naples, FL	09/06/04 08:06	1.312	0.616	1.003
8725520	Fort Myers, FL	09/06/04 11:00	1.221	0.903	1.261
8726384	Port Manatee, FL	09/06/04 13:00	1.412	0.937	-0.435
8726520	St. Petersburg, FL	09/06/04 14:48	1.537	1.094	1.363
8726724	Clearwater Beach, FL	09/06/04 11:42	1.325	0.780	1.043
8727520	Cedar Key, FL	09/06/04 19:18	2.014	1.327	1.538

Trident Pier recorded the second highest surge value at 1.270 m. The remainder of the water level stations from Mayport near Jacksonville to Clearwater Beach recorded storm surge values of approximately one meter.

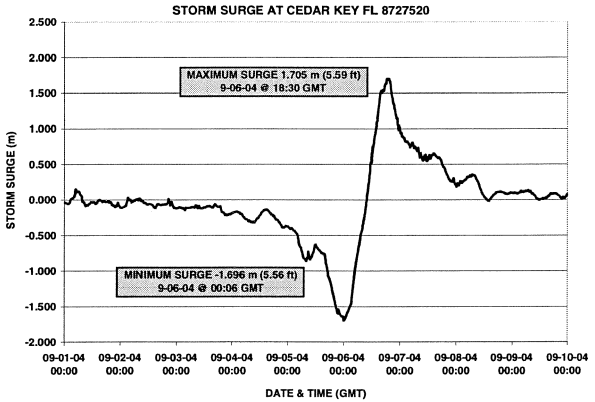

Figure 5. Storm surge at Cedar Key, FL

Table 4. Maximum observed storm surge during hurricane FRANCES.

Maximum Storm Surge (Greatest Difference Between Observed and Predicted)					
Station ID	**Station Name**	**Date/Time GMT**	**Observed Water Level Above MLLW(m)**	**Predicted Water Levels (m)**	**Maximum Surge (m)**
8720211	Mayport Naval , FL	09/05/04 23:24	1.208	0.326	0.882
8720218	Mayport, FL	09/05/04 23:24	1.225	0.475	0.750
8720226	Main Street Bridge, FL	09/06/04 13:42	0.999	0.069	0.930
8720357	I-295 Bridge, FL	09/06/04 14:06	0.953	0.032	0.921
8720503	Red Bay Point, FL	09/06/04 15:06	0.873	0.067	0.806
8720554	***Vilano Beach, FL**	09/06/04 01:00	1.187	0.276	**0.911**
8720625	Racy Point, FL	09/06/04 04:12	0.820	0.141	0.679
8720651	Crescent Beach, FL	09/06/04 00:54	1.369	0.286	*1.083*
8720757	Bings Landing, FL	09/06/04 02:18	1.151	0.400	0.751
8720767	Buffalo Bluff, FL	09/06/04 04:42	0.963	0.439	0.524
8720774	***Palatka, FL**	09-06-04 04:06	0.986	0.464	**0.522**
8721604	Trident Pier, FL	09/05/04 11:06	1.479	0.209	*1.270*
8725110	Naples, FL	09/05/04 17:18	0.912	0.280	0.632
8725520	Fort Myers, FL	09/06/04 09:06	1.125	0.270	0.855
8726384	Port Manatee, FL	09/06/04 16:24	1.211	0.266	0.945
8726520	St. Petersburg, FL	09/06/04 14:48	1.537	0.453	*1.084*
8726724	Clearwater Beach, FL	09/06/04 15:24	1.118	0.276	0.842
8727520	Cedar Key, FL	09/06/04 18:30	1.974	0.269	*1.705*
8727520	Cedar Key, FL	09-06-04 00:06	-0.841	0.855	*-1.696*
NOTE: Cedar Key experienced both a positive and negative surge within a 24 hour period					
*** Gauge Limit Exceeded**. No true maximum recorded.					

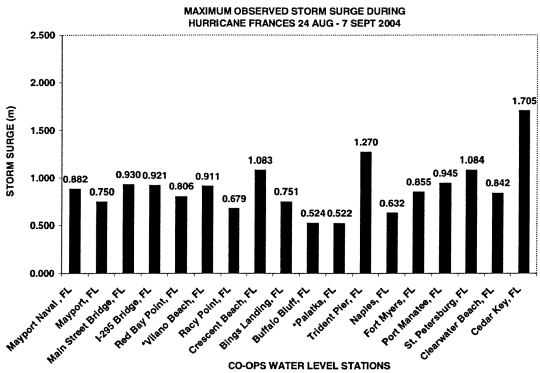

Figure 6. Maximum observed storm surge during hurricane FRANCES.

HURRICANE IVAN

Hurricane IVAN which made initial landfall as a Category 3 hurricane on 16 September near Gulf Shores, AL was the strongest storm of the season reaching Category 5 strength after it passed over Grenada in the Caribbean. The highest maximum observed water level recorded was at Pensacola, Fl (2.230 m) though this gauge was destroyed by the storm and an exact water level cannot be recovered. The next three highest observed water levels were at Dauphin Island (2.177 m), Panama City Beach (1.963 m), and Cedar Key (1.913 m) (Table 5). Water levels at Apalachicola and Panama City were slightly less at 1.596 m and 1.443 m respectively. The remainder of the stations to the east and west of landfall recorded water levels of approximately 0.800 m to 1.400 m. IVAN reformed into a tropical depression on 22 September in the Gulf of Mexico after travelling in a circular motion through the southeastern United States and made landfall near Cameron, LA The highest observed water level during this event was recorded at Galveston Pleasure Pier (1.322 m). Freeport and Corpus Christi, TX recorded the second and third highest with 1.197 m and 1.173 m respectively.

Table 5. Maximum observed water levels during hurricane IVAN.

Maximum Observed Water Levels Refered to MLLW, NAVD 88 and NGVD29					
Station ID	Station Name	Date-Time	Maximum Observed Water Level Above MLLW (m)	Maximum Observed Water Level Above NAVD 88 (m)	Maximum Observed Water Level Above NGVD 29 (m)
8723970	Vaca Key, FL	09-22-04 10:06	0.569	0.162	0.589
8724580	Key West, FL	09-14-04 14:24	0.773	0.235	0.644
8725110	Naples, FL	09-15-04 17:18	1.228	0.532	0.955
8725520	Fort Myers, FL	09-15-04 20:42	0.829	0.511	0.869
8726384	Port Manatee, FL	09-15-04 18:42	1.261	-0.147	0.122
8726520	St Petersburg, FL	09-15-04 19:00	1.343	2.371	2.371
8726724	Clearwater Beach, FL	09-15-04 17:54	1.509	0.964	1.227
8727520	Cedar Key, FL W1	09-15-04 19:42	1.913	1.226	1.437
8728690	Apalachicola, FL	09-16-04 06:54	1.596	1.364	1.537
8729108	Panama City, FL	09-16-04 12:12	1.443	1.273	1.417
8729210	Panama City Beach, FL	09-16-04 06:00	1.963	N/A	N/A
8729840	***Pensacola, FL**	09-16-04 05:36	***2.230**	2.132	N/A
8735180	Dauphin Is., AL	09-16-04 04:06	2.177	2.107	2.066
8737373	****Lower Bryant Landing, AL**	09-16-04 19:18	****1.450**	1.450	1.450
8744117	Biloxi, MS	09-16-04 03:30	1.240	1.240	1.240
8747766	Waveland, MS	09-16-04 06:48	1.450	1.384	1.339
8760922	South West Pass, LA	09-16-04 02:00	1.164	1.164	1.164
8761724	Grand Isle, LA	09-15-04 17:06	0.875	1.041	0.948
8762075	Port Fourchon, LA	09-16-04 06:54	0.965	N/A	N/A
8762372	Bayou La Branche, LA	09-16-04 04:24	0.871	N/A	N/A
8770570	Sabine Pass North, TX	09-22-04 05:54	0.956	N/A	N/A
8770613	Morgans Point, TX	09-22-04 14:00	1.111	N/A	1.106
8771013	Eagle Point, TX	09-22-04 14:00	1.156	N/A	N/A
8771341	Galveston Bay, North Jetty, TX	09-22-04 09:42	1.155	N/A	N/A
8771450	Galveston Pier 21, TX	09-22-04 11:54	1.056	1.013	1.010
8771510	Galveston Pleasure Pier, TX	09-22-04 09:18	1.322	1.136	1.184
8772440	Freeport, TX	09-22-04 09:42	1.197	N/A	N/A
8774770	Rockport, TX	09-23-04 13:54	0.693	0.864	N/A
8775870	Corpus Christi, TX	09-23-04 06:24	1.173	1.037	0.691
8779770	Port Isabel, TX	09-23-04 08:30	0.932	0.672	N/A
*** Gauge destroyed **Data Inferred**					

Storm surge resulting from hurricane IVAN was greatest at Pensacola (1.892 m) though as stated above this value is only a partial record (Table 6 and Figure 7). Fifteen miles to the west Dauphin Island recorded a surge of 1.885 m (Figure 8). Stations in the region to the west of the storms track such as Biloxi, MS, Waveland, MS and South West Pass, LA recorded storm surges of 1.001 m, 1.055 m, and 0.894 m. respectively. To the east Panama City Beach recorded a surge of 1.623 m, and Panama City recorded a surge of 1.229 m. During IVAN's second landfall Eagle Point, TX recorded the highest surge at 0.596 m. The rest of the stations along the Texas coastline recorded similar levels that averaged approximate 0.5 m.

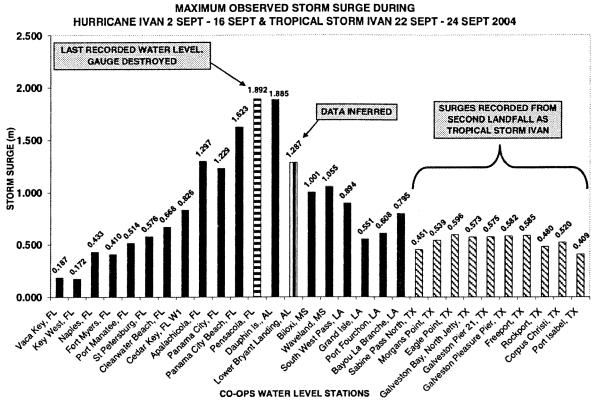

Figure 7. Maximum observed storm surge during hurricane IVAN.

Table 6. Maximum observed storm surge during hurricane IVAN.

Maximum Storm Surge (Greatest Difference Between Observed and Predicted)					
Station ID	Station Name	Date-Time	Obsverved Water Level Above MLLW (m)	Predicted Water Levels (m)	Maximum Surge (m)
8723970	Vaca Key, FL	09-21-04 23:54	0.366	0.179	0.187
8724580	Key West, FL	09-14-04 09:18	0.409	0.237	0.172
8725110	Naples, FL	09-15-04 10:24	0.682	0.249	0.433
8725520	Fort Myers, FL	09-15-04 17:24	0.629	0.219	0.410
8726384	Port Manatee, FL	09-15-04 19:00	1.259	0.745	0.514
8726520	St Petersburg, FL	09-15-04 19:00	1.343	0.767	0.576
8726724	Clearwater Beach, FL	09-15-04 10:42	0.861	0.193	0.668
8727520	Cedar Key, FL W1	09-15-04 23:48	1.183	0.357	0.826
8728690	Apalachicola, FL	09-16-04 03:12	1.507	0.210	1.297
8729108	Panama City, FL	09-16-04 12:12	1.443	0.214	1.229
8729210	Panama City Beach, FL	09-16-04 06:00	1.963	0.340	1.623
8729840	Pensacola, FL	09-16-04 05:36	2.230	0.338	*1.892
8735180	Dauphin Is., AL	09-16-04 04:06	2.177	0.292	1.885
8737373	Lower Bryant Landing, AL	09-16-04 18:30	1.442	0.155	**1.287
8744117	Biloxi, MS	09-16-04 03:18	1.234	0.233	1.001
8747766	Waveland, MS	09-16-04 06:48	1.450	0.395	1.055
8760922	South West Pass, LA	09-16-04 00:54	1.153	0.259	0.894
8761724	Grand Isle, LA	09-15-04 17:06	0.875	0.324	0.551
8762075	Port Fourchon, LA	09-16-04 09:18	0.931	0.323	0.608
8762372	Bayou La Branche, LA	09-16-04 04:24	0.871	0.076	0.795
8770570	Sabine Pass North, TX	09-22-04 17:54	0.742	0.291	0.451
8770613	Morgans Point, TX	09-23-04 00:24	0.621	0.082	0.539
8771013	Eagle Point, TX	09-22-04 16:36	1.093	0.497	0.596
8771341	Galveston Bay, North Jetty, TX	09-22-04 15:42	1.036	0.463	0.573
8771450	Galveston Pier 21, TX	09-22-04 15:54	1.005	0.430	0.575
8771510	Galveston Pleasure Pier, TX	09-22-04 09:18	1.322	0.740	0.582
8772440	Freeport, TX	09-22-04 09:42	1.197	0.612	0.585
8774770	Rockport, TX	09-23-04 06:06	0.607	0.127	0.480
8775870	Corpus Christi, TX	09-15-04 18:36	0.951	0.431	0.520
8779770	Port Isabel, TX	09-23-04 20:06	0.532	0.123	0.409
* Gauge Destroyed **Data Inferred					

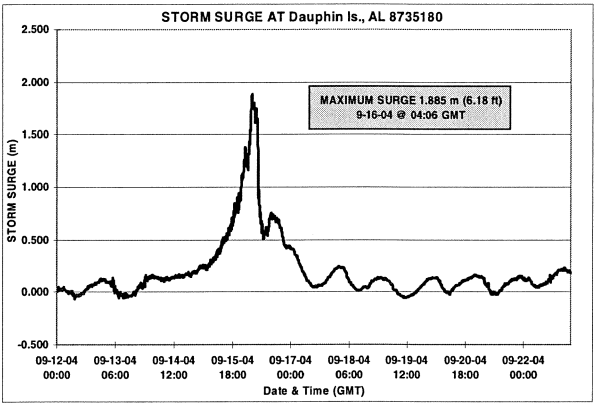

Figure 8. Storm surge at Dauphin Island, AL.

HURRICANE JEANNE

Hurricane JEANNE's track followed to within 20 miles of that of FRANCES and made landfall just east of Stuart, FL. Maximum observed water levels were the highest along the US coastaline to the north of landafll at St. Simons Island, GA (2.884 m), Fernandina Beach, FL (2.845 m), and Fripps Inlet, SC (2.542 m) (Table 7). Farther to the south nearest the location of landfall Trident Pier recorded a maximum observed water level of 2.469 m. Locations in the Caribbean that JEANNE impacted were Lime Tree Bay, VI, Charlotte Amalie, VI and San Juan, PR which recorded maximum water levels of 0.581 m, 0.423 m, and 0.664 m respectfully.

Table 7. Maximum observed water levels during hurricane JEANNE.

Maximum Observed Water Levels Referred to MLLW, NAVD 88 and NGVD 29					
Station ID	Station Name	Date/Time GMT	Maximum Observed Water Level Above MLLW (m)	Maximum Observed Water Level Above NAVD88 (m)	Maximum Observed Water Level Above NGVD 29(m)
9751401	Lime Tree Bay, VI	09-15-04 10:30	0.581	NA	NA
9751639	Charlotte Amalie, VI	09-21-04 20:00	0.423	NA	NA
9755371	San Juan, PR	09-18-04 15:48	0.664	NA	NA
9759110	Magueyes, PR	09-24-04 00:36	0.334	NA	NA
8664941	South Capers Island, SC	09-28-04 00:24	2.170	1.959	2.259
8665530	Charleston, SC	09-28-04 00:24	2.199	1.242	1.541
8668498	Fripps Inlet, SC	09-26-04 23:54	2.542	1.428	1.710
8677344	St. Simons Island, GA	09-27-04 00:00	2.884	1.607	NA
8720030	Fernandina Beach, FL	09-27-04 01:06	2.845	1.680	NA
8720218	Bar Pilots Dock, FL	09-27-04 00:36	2.306	NA	NA
8720226	Main Street Bridge, FL	09-27-04 03:24	1.653	NA	NA
8720503	Red Bay Point, FL	09-27-04 05:24	1.219	1.023	1.333
8720774	Palatka, FL	09-26-04 20:42	1.267	NA	NA
8721604	Trident Pier, FL	09-30-04 23:54	2.469	NA	NA
8723214	Virginia Key, FL	09-26-04 11:36	1.078	0.470	NA
8725110	Naples, FL	09-26-04 13:36	1.481	0.785	1.172
8725520	Fort Myers, FL	09-26-04 19:12	1.160	0.842	1.200
8726724	Clearwater Beach, FL	09-26-04 15:48	1.178	0.633	0.896
8727520	Cedar Key, FL	09-27-04 07:30	1.887	1.200	1.411

Storm surge resulting from hurricane JEANNE was greatest at Trident Pier (1.282 m) (Table 8 and Figure 9). Main Street Bridge, on the St. Johns river and Fernandina Beach recorded the second and third highest with 1.273 m and 1.215 m respectively. Similar to surges during FRANCES Cedar Key experienced both a positive and negative surge within a 24 hour period (1.107 m and -1.289 m).