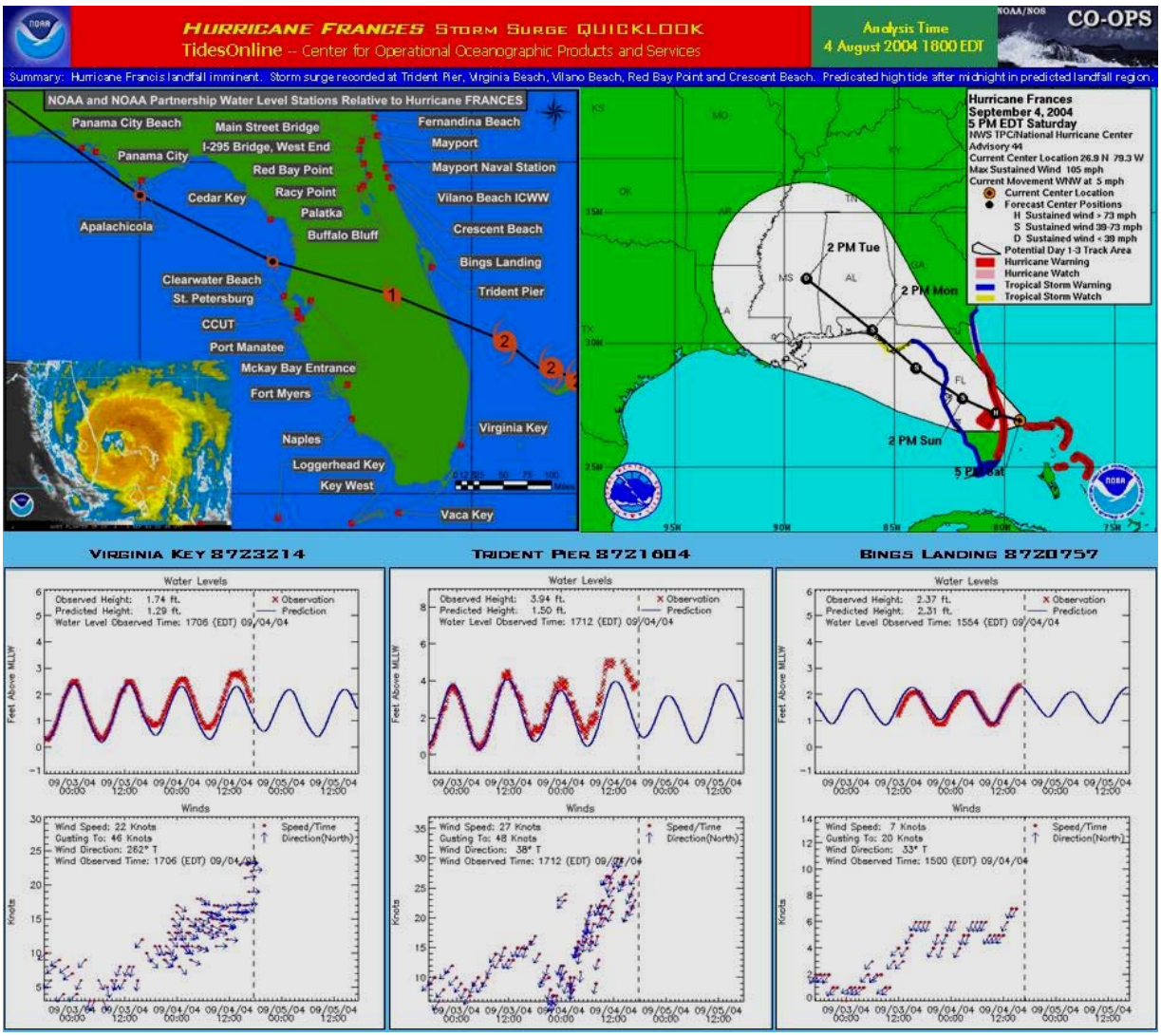
Hurricane FRANCES Preliminary water Levels report



*For the purpose of timely release, data contained within this report have undergone "limited" NOS Quality Assurance/Control; however, the data have not yet undergone final verification. All data subject to NOS verification.

October 2004

noaa **National Oceanic and Atmospheric Administration**

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

SUMMARY

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) maintains a network of water level gauges within the Gulf of Mexico, the U.S. Virgin Islands and Puerto Rico. During the hurricane season (June through November), CO-OPS personnel can trigger gauges for real-time monitoring in storm surge mode on the World Wide Web Tides Online (www.tidesonline.nos.noaa.gov). To further improve data access, CO-OPS instituted a new product, referred to as the "Storm Tide Quicklook" (Coverpage). The Quicklooks provided a summary of impacted water level stations and supporting meteorological data in a one click format (Table 1).

Table 1. "Storm Tide Quicklook" Product - Hurricane Frances Water Level Summaries

Quicklook	Date	Time (EDT)	Hurricane Category	# Stations Presented
1	9/4/2004	10:00	2	4
2	9/4/2004	18:00	2	10
3	9/5/2004	10:00	1	8
4	9/5/2004	18:00	TS	10
5	9/6/2004	01:00	TS	7
6	9/6/2004	10:00	TS	9
7	9/6/2004	18:00	TS	9

Currently, there are 2 Alabama stations and 33 Florida stations, including 8 stations available through a NOAA partnership with the Florida Department of Environmental Protection (FDEP), Bureau of Mapping and Surveying (www.dep.state.fl.us/lands/surv_map) (Figure 1). There are 2 stations in the U.S. Virgin Islands and 2 in Puerto Rico (Figure 2). In addition, many of the CO-OPS stations also collected meteorological data (air temperature, barometric pressure, wind speed and direction) and water temperature during the storm. Operational stations within the path of Hurricane Frances are evaluated in this report.

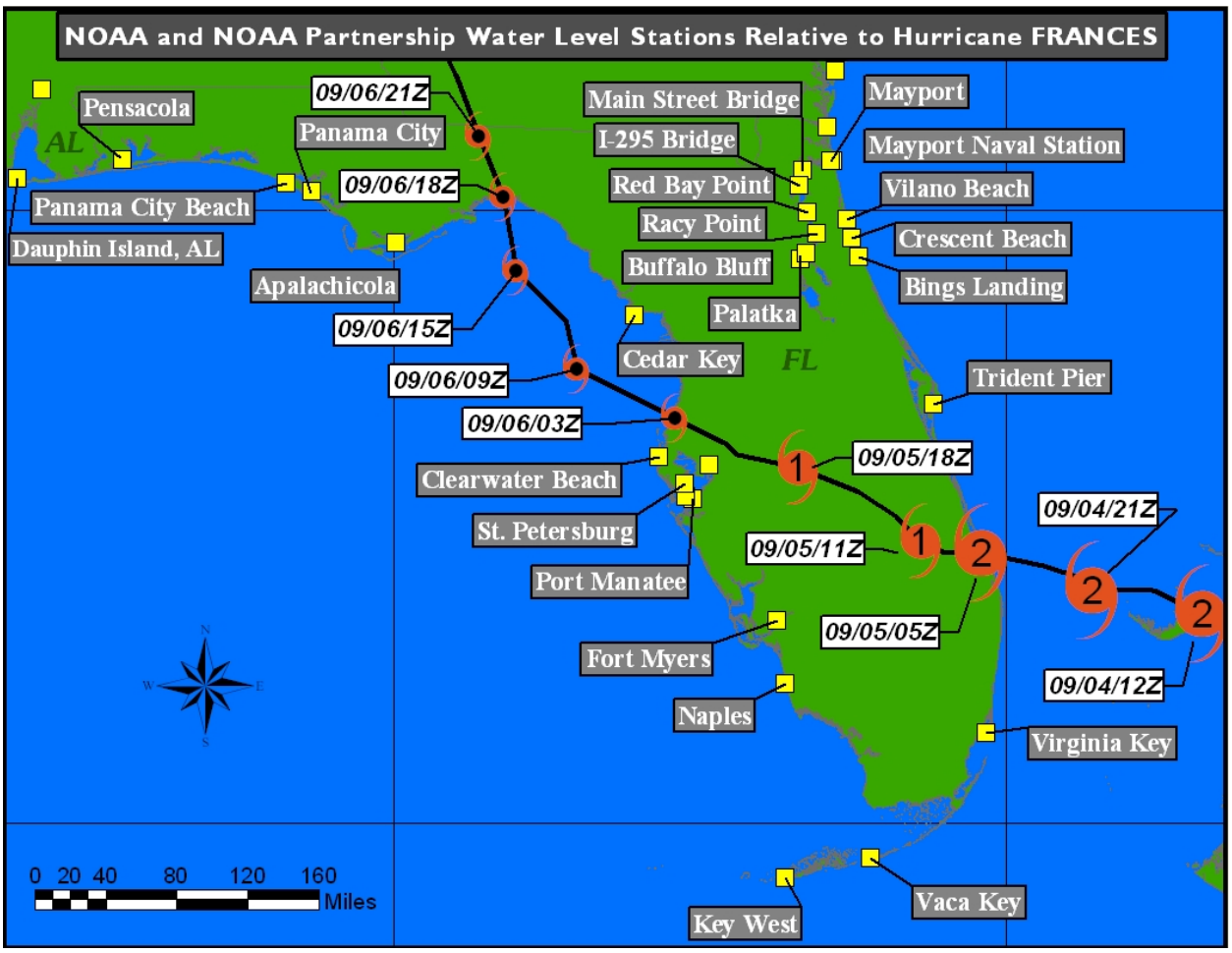


Figure 1. Alabama and Florida water level stations within the path of Hurricane Frances.

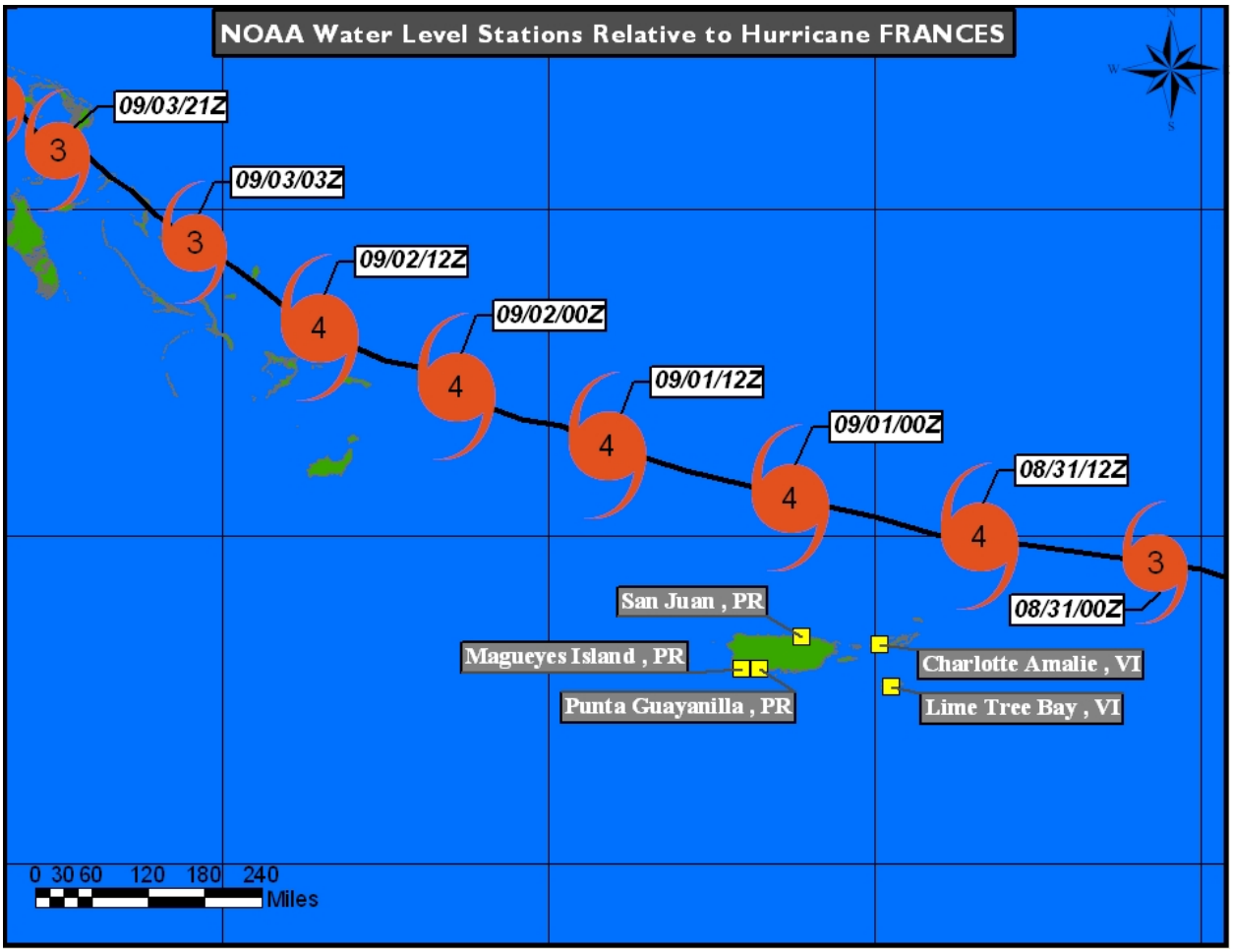


Figure 2. Puerto Rico and U.S. Virgin Islands water level stations within the path of Hurricane Frances.

This data report begins with description of the inception, development and response of water levels to Hurricane Frances. The maximum observed water levels are tabulated and include the date, time and heights of above Mean Lower Low Water (MLLW). Also included are water level heights relative to geodetic datums, the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29). Unless otherwise stated, all other height references, including time series plots, are relative to MLLW. MLLW is the reference datum for NOAA nautical charts and NOS tide prediction tables and is based on the 1983-2001 National Tidal Datum Epoch.

The maximum observed water levels are dependant upon many factors including the interaction of the tide and the storm. The timing of the maximum water levels does not necessarily coincide with the occurrence of the maximum storm surge. Storm surge is defined by NOS as the local change in elevation of the ocean along a shore due to a storm. Storm surge is computed as the difference between the observed and the predicted tide curve. For example, if the peak storm surge occurs before or after a predicted high tide, the tide was adding on to the surge; otherwise, the tide was working against the surge. In the final section of the report, maximum storm surges are tabulated for stations impacted by Hurricane Frances.

Maximum Water Levels Analysis

A major concern during a storm is the maximum water level reached, as this determines the potential for damage. Maximum water levels occur based on the effect of high wind speed and low atmospheric pressure, in addition to the timing and strength of the tide when the storm reaches its peak. If a storm occurs during a low tide and/or during a period of neap tides, the maximum water level can be significantly less than when a storm occurs at high tide and/or during a period of spring tides. The analysis period of Hurricane Frances (August 30-September 7) fell between a full moon on August 30th and the last quarter on September 6th. Therefore, the tides were in between the spring (higher) and neap (lower) tide phases. If the hurricane had coincided with either a full moon or a new moon, higher maximum water levels would have occurred. However, the moon was in perigee, closest to the earth, producing higher than usual tide-generating forces during Hurricane Frances.

Maximum water levels are displayed in geographical order for easy reference (Table 2) and by date for comparison to Frances's progression (Table 3). The timing of the maximum water levels are compared with Frances's location using National Hurricane Center (NHC) advisories and graphics (Courtesy of the NOAA NHC). Time series plots of the observed water levels are presented without smoothing the data.

Table 2. By geographical order, maximum water level data for Hurricane Frances relative to MLLW, NAVD 88, and NGVD 29, if available. Minimum (shaded values) water levels are included for stations that experienced receded water levels.
*Operated by FDEP.
[1]Stations whose data flatlined at the maximum water level due to reaching sensor limit
[2]Stations whose data flatlined at the minimum water levels due to reaching sensor limit
[3]Stations where the maximum water level value is also the maximum storm surge value.

*For the purpose of timely release, data contained within this report have undergone "limited" NOS Quality Assurance/Control; however, the data have not yet undergone final verification. All data subject to NOS verification.

Station Name	Station ID	Date/Time (EDT)	Date/Time (GMT/Z)	Elevation Above (m):		
				MLLW	*NAVD 88*	*NGVD 29*
Mayport, FL	8720218	09/05/04 13:54	09/05/04 17:54	1.837	n/a	n/a
*Mayport Naval , FL	8720211	09/05/04 13:48	09/05/04 17:48	1.935	n/a	n/a
[1]Vilano Beach, FL	8720554	09/05/04 13:30	09/05/04 17:30	1.835	n/a	n/a
*Crescent Beach, FL	8720651	09/05/04 15:36	09/05/04 19:36	2.019	n/a	n/a
*Bings Landing, FL	8720757	09/05/04 17:48	09/05/04 21:48	1.277	n/a	n/a
*Main Street Bridge, FL	8720226	09/06/04 04:18	09/06/04 08:18	1.373	0.957	n/a
*I-295 Bridge, FL	8720357	09/06/04 04:48	09/06/04 08:48	1.125	n/a	n/a
*Red Bay Point, FL	8720503	09/06/04 05:48	09/06/04 09:48	1.000	n/a	n/a
Racy Point, FL	8720625	09/06/04 08:18	09/06/04 12:18	0.953	0.744	n/a
[1]*Palatka, FL	8720774	09/06/04 00:06	09/06/04 04:06	0.986	n/a	n/a
*Buffalo Bluff, FL	8720767	09/05/04 21:48	09/06/04 01:48	1.063	n/a	n/a
Trident Pier, FL	8721604	09/05/04 11:54	09/05/04 15:54	2.158	n/a	n/a
Virginia Key, FL	8723214	09/05/04 01:30	09/05/04 05:30	0.917	0.309	n/a
Vaca Key, FL	8723970	09/05/04 06:48	09/05/04 10:48	0.676	0.269	0.696
Key West, FL	8724580	09/04/04 01:12	09/04/04 05:12	0.677	0.139	0.548
Naples, FL	8725110	09/06/04 04:06	09/06/04 08:06	1.312	0.616	1.003
Fort Myers, FL	8725520	09/04/04 16:30	09/04/04 20:30	-0.043	-0.361	-0.003
Fort Myers, FL	8725520	09/06/04 07:00	09/06/04 11:00	1.221	0.903	1.261
Port Manatee, FL	8726384	09/06/04 09:00	09/06/04 13:00	1.412	0.937	-0.435
St. Petersburg, FL	8726520	09/05/04 13:42	09/05/04 17:42	-0.138	-0.581	-0.312
[3]St. Petersburg, FL	8726520	09/06/04 10:48	09/06/04 14:48	1.537	1.094	1.363
Clearwater Beach, FL	8726724	09/05/04 11:42	09/05/04 15:42	0.033	-0.512	-0.249
Clearwater Beach, FL	8726724	09/06/04 07:42	09/06/04 11:42	1.325	0.780	1.043
[2]Cedar Key, FL	8727519	09/05/04 15:12	09/05/04 19:12	-0.850	-0.537	-0.326
Cedar Key, FL	8727520	09/06/04 15:18	09/06/04 19:18	2.014	1.327	1.538
[2]Apalachicola, FL	8728690	09/05/04 11:24	09/05/04 15:24	-0.079	-0.311	-0.138
Apalachicola, FL	8728690	09/07/04 06:54	09/07/04 10:54	0.756	0.524	0.697
Panama City, FL	8729108	09/05/04 20:36	09/06/04 00:36	-0.265	-0.435	-0.291
Panama City Beach, FL	8729210	09/05/04 20:18	09/06/04 00:18	-0.335	n/a	n/a
Pensacola, FL	8729840	09/06/04 17:12	09/06/04 21:12	-0.214	-0.312	n/a
Dauphin Island , AL	8735180	09/06/04 17:30	09/06/04 21:30	-0.187	-0.257	-0.298
Lime Tree Bay, VI	9751401	08/30/04 23:36	08/31/04 03:36	0.356	n/a	n/a
Charlotte Amalie, VI	9751639	08/30/04 21:36	08/31/04 01:36	0.582	n/a	n/a
San Juan, PR	9755371	08/30/04 21:24	08/31/04 01:24	0.408	n/a	n/a
[3]Punta Guayanilla, PR	9758053	09/03/04 16:24	09/03/04 20:24	0.361	n/a	n/a
[3]Magueyes Island, PR	9759110	09/03/04 17:18	09/03/04 21:18	0.351	n/a	n/a

Table 3. By date, maximum water level data for Hurricane Frances relative to MLLW, NAVD 88, and NGVD 29, if available. Minimum (shaded values) water levels are included for stations that experienced receded water levels.

*Operated by FDEP.
[1]Stations whose data flatlined at the maximum water level due to reaching sensor limit
[2]Stations whose data flatlined at the minimum water levels due to reaching sensor limit
[3]Stations where the maximum water level value is also the maximum storm surge value.

*For the purpose of timely release, data contained within this report have undergone "limited" NOS Quality Assurance/Control; however, the data have not yet undergone final verification. All data subject to NOS verification.

Station Name	Station ID	Date/Time (EDT)	Date/Time (GMT/Z)	Elevation Above (m):		
				MLLW	*NAVD 88*	*NGVD 29*
San Juan, PR	9755371	08/30/04 21:24	08/31/04 01:24	0.408	n/a	n/a
Charlotte Amalie, VI	9751639	08/30/04 21:36	08/31/04 01:36	0.582	n/a	n/a
Lime Tree Bay, VI	9751401	08/30/04 23:36	08/31/04 03:36	0.356	n/a	n/a
[3]Punta Guayanilla, PR	9758053	09/03/04 16:24	09/03/04 20:24	0.361	n/a	n/a
[3]Magueyes Island, PR	9759110	09/03/04 17:18	09/03/04 21:18	0.351	n/a	n/a
Key West, FL	8724580	09/04/04 01:12	09/04/04 05:12	0.677	0.139	0.548
Fort Myers, FL	8725520	09/04/04 16:30	09/04/04 20:30	-0.043	-0.361	-0.003
Virginia Key, FL	8723214	09/05/04 01:30	09/05/04 05:30	0.917	0.309	n/a
Vaca Key, FL	8723970	09/05/04 06:48	09/05/04 10:48	0.676	0.269	0.696
[2]Apalachicola, FL	8728690	09/05/04 11:24	09/05/04 15:24	-0.079	-0.311	-0.138
Clearwater Beach, FL	8726724	09/05/04 11:42	09/05/04 15:42	0.033	-0.512	-0.249
Trident Pier, FL	8721604	09/05/04 11:54	09/05/04 15:54	2.158	n/a	n/a
[1]Vilano Beach, FL	8720554	09/05/04 13:30	09/05/04 17:30	1.835	n/a	n/a
St. Petersburg, FL	8726520	09/05/04 13:42	09/05/04 17:42	-0.138	-0.581	-0.312
*Mayport Naval , FL	8720211	09/05/04 13:48	09/05/04 17:48	1.935	n/a	n/a
Mayport, FL	8720218	09/05/04 13:54	09/05/04 17:54	1.837	n/a	n/a
[2]Cedar Key, FL	8727519	09/05/04 15:12	09/05/04 19:12	-0.850	-0.537	-0.326
*Crescent Beach, FL	8720651	09/05/04 15:36	09/05/04 19:36	2.019	n/a	n/a
*Bings Landing, FL	8720757	09/05/04 17:48	09/05/04 21:48	1.277	n/a	n/a
Panama City Beach, FL	8729210	09/05/04 20:18	09/06/04 00:18	-0.335	n/a	n/a
Panama City, FL	8729108	09/05/04 20:36	09/06/04 00:36	-0.265	-0.435	-0.291
*Buffalo Bluff, FL	8720767	09/05/04 21:48	09/06/04 01:48	1.063	n/a	n/a
[1]*Palatka, FL	8720774	09/06/04 00:06	09/06/04 04:06	0.986	n/a	n/a
Naples, FL	8725110	09/06/04 04:06	09/06/04 08:06	1.312	0.616	1.003
*Main Street Bridge, FL	8720226	09/06/04 04:18	09/06/04 08:18	1.373	0.957	n/a
*I-295 Bridge, FL	8720357	09/06/04 04:48	09/06/04 08:48	1.125	n/a	n/a
*Red Bay Point, FL	8720503	09/06/04 05:48	09/06/04 09:48	1.000	n/a	n/a
Fort Myers, FL	8725520	09/06/04 07:00	09/06/04 11:00	1.221	0.903	1.261
Clearwater Beach, FL	8726724	09/06/04 07:42	09/06/04 11:42	1.325	0.780	1.043
Racy Point, FL	8720625	09/06/04 08:18	09/06/04 12:18	0.953	0.744	n/a
Port Manatee, FL	8726384	09/06/04 09:00	09/06/04 13:00	1.412	0.937	-0.435
[3]St. Petersburg, FL	8726520	09/06/04 10:48	09/06/04 14:48	1.537	1.094	1.363
Cedar Key, FL	8727520	09/06/04 15:18	09/06/04 19:18	2.014	1.327	1.538
Pensacola, FL	8729840	09/06/04 17:12	09/06/04 21:12	-0.214	-0.312	n/a
Dauphin Island , AL	8735180	09/06/04 17:30	09/06/04 21:30	-0.187	-0.257	-0.298
Apalachicola, FL	8728690	09/07/04 06:54	09/07/04 10:54	0.756	0.524	0.697

Tuesday, August 24th

The initial advisory for the 6th Tropical Depression of the 2004 Hurricane Season was issued on Tuesday, August 24 at 2300 EDT/ 0300Z (Figure 3). Tropical Depression Frances originated 870 miles west southwest of the Cape Verde Islands (11.2° N, 36.0° W).

Frances became a Tropical Storm on Wednesday, August 25, with increased winds of 40 mph. By Thursday, August 26, Frances had strengthened into the 4th hurricane of the 2004 season.

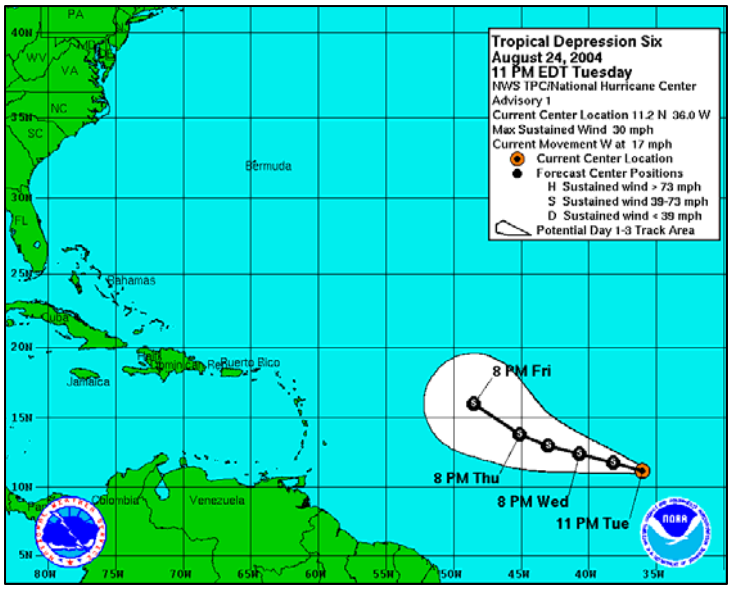


Figure 3. NHC Initial Advisory Graphic 1.

Frances increased in strength and became a Category 2 hurricane at 1100 EDT/ 1500Z on Friday, August 27. Frances was located 820 miles east of Lesser Antilles and was moving west northwest at 10 mph with winds nearing 105 mph. The eye of the hurricane continued to intensify into the evening and at 1700 EDT/ 2100Z Frances became a Category 3 hurricane.

Saturday, August 28

On Saturday, August 28, Frances had slowed down in speed, but continued to pick up force. At 1700 EDT/2100Z, August 28, Frances became the 2nd Category 4 hurricane of the season. Winds had strengthened to 135 mph as Frances continued to move west northwest. On Sunday, August 29, at 1700 EDT/2100Z, warnings were issued for most of the Caribbean with Frances located 480 miles east of Leeward Islands (18.8° N, 55.8° W).

Monday, August 30

Tropical Storm warnings were issued for Puerto Rico and the U.S. Virgin Islands on Monday, August 30. The max sustained winds had reached 125 mph and the force winds extended 70 miles outward. Frances continued to move west into Tuesday, August 31 (Figure 4). The San Juan station in Puerto Rico experienced maximum water levels at 0124Z (0.408 m). This was followed by maximums at the U.S. Virgin Islands, including Charlotte Amalie (0.582 m, 0136Z) and Lime Tree Bay (0.356 m, 0336Z).

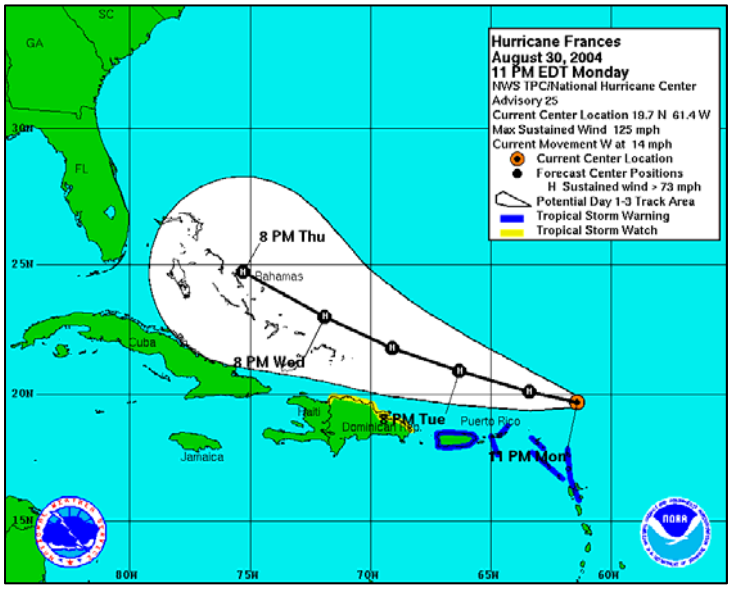


Figure 4. NHC Advisory Graphic 25.

Warnings remained in effect for most of the Leeward Islands. On Wednesday, September 1, Hurricane Frances sustained winds of 140 mph and a Category 4 status.

By Thursday, September 2, Hurricane warnings were issued for the eastern coast of Florida extending up towards Lake Okeechobee. By 2300 EDT/ 0300Z, Frances had weakened slightly to a Category 3 Hurricane.

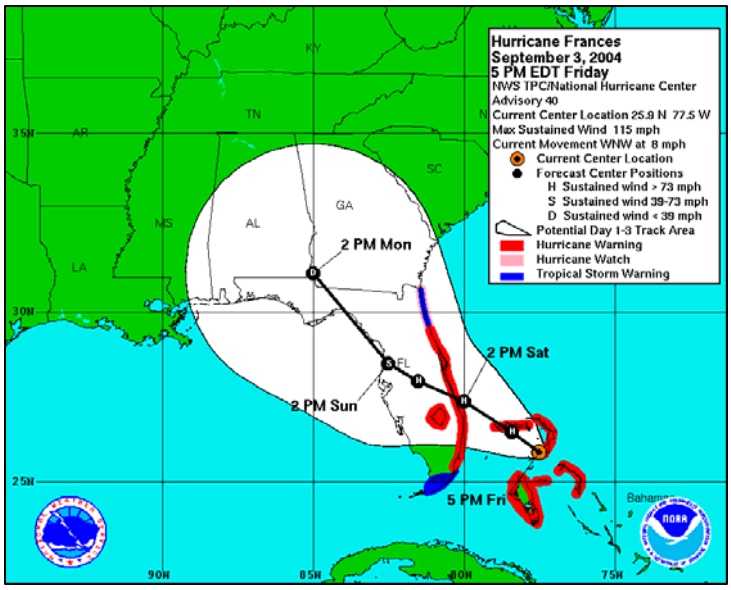


Figure 5. NHC Advisory Graphic 40.

Friday, September 3

Long after Frances had passed, at 2024Z on Friday, September 3, Puerto Rico experienced elevated water levels on the south side of the island (Figure 2). Maximum water levels occurred at Punta Guayanilla (0.361 m, 2024Z) and Magueyes Island (0.351 m, 2118Z; Figure 6). The maximum water levels also coincided with maximum storm surge. In addition, the timing coincided with a high tide period, for even higher water elevations. By 2300 EDT/ 0300Z, Frances was 150 miles east southeast of West Palm Beach, FL (26.1^{o} N, 77.8^{o} W). Frances had downgraded to a Category 2 hurricane, moving at 6 mph with sustained winds of 105 mph.

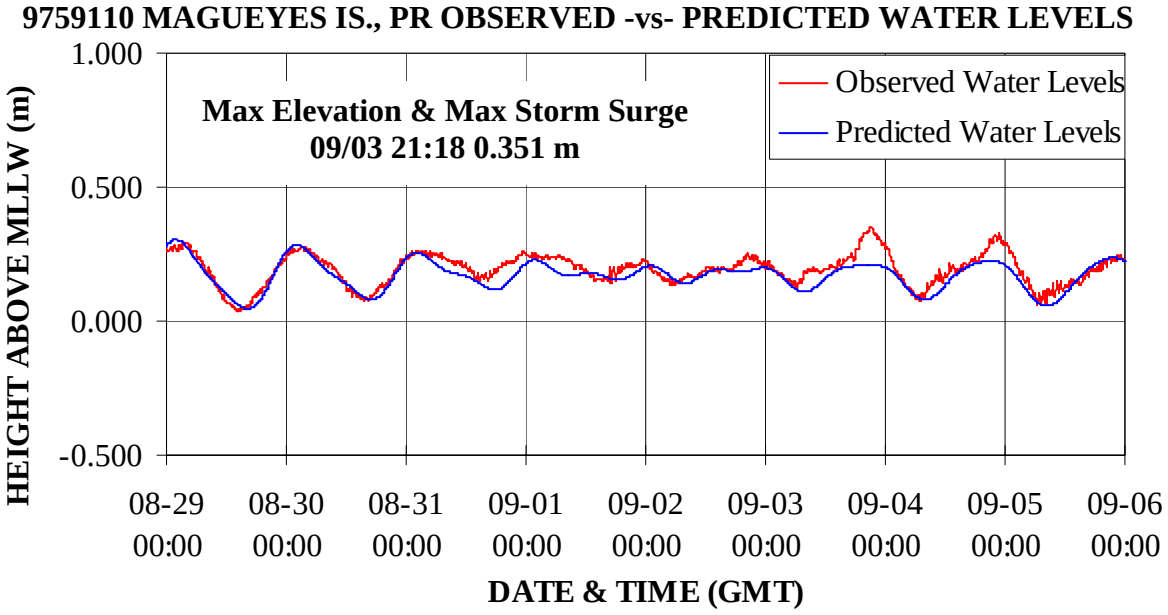


Figure 6. Time series of observed water levels and predicted tides for Magueyes Island, PR.

Saturday, September 4

Hurricane warnings for Florida's eastern shore continued through Saturday, September 4, as Frances remained stationary in the Atlantic. On that day, the Key West station was the first Florida station to reach a maximum water elevation from the hurricane (0.677 m, 0512Z). In addition, the west coast of Florida began experiencing receding water levels, with the Fort Myers station reaching the minimum water level (-0.043 m, 2030Z).

Sunday, September 5

At 0100 EDT/ 0500Z on Sunday, September 5, the eye of Frances made landfall near Sewell's point, FL. At nearly the same time, Virginia Key station reached the maximum water level of 0.917 m at 0530Z (Figure 7).

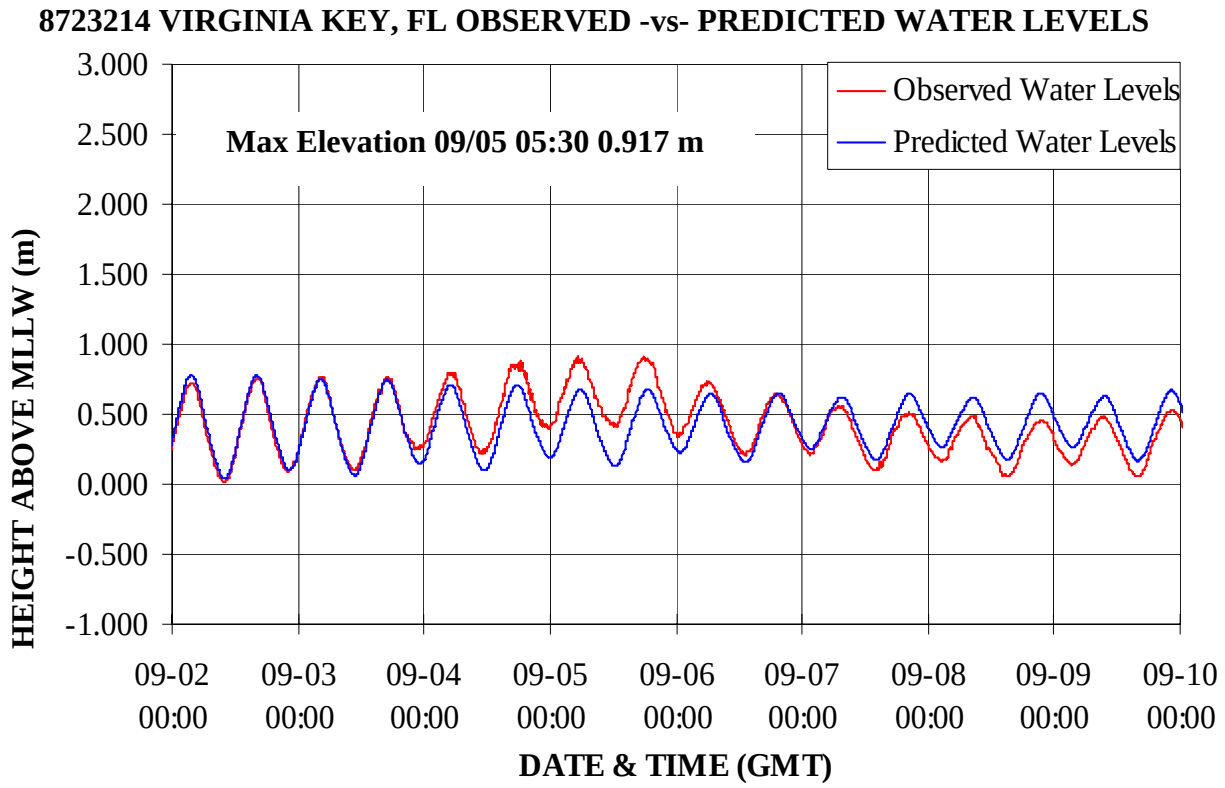


Figure 7. Time series of observed water levels and predicted tides for Virginia Key, FL.

By 0700 EDT/ 1100Z, Frances was above Lake Okeechobee and had downgraded to Category 1. However, even at Category 1, between 1100 - 16:00 EDT/ 1500 - 2000Z, five out of six top maximum water levels occurred, including Trident Pier, Crescent Beach, Mayport Naval, Mayport, and Vilano Beach, with water levels between 1.835 - 2.158 m above MLLW (Figure 8 - Figure 11). Trident Pier and Port Manatee were the only stations in which Frances's maximum water levels superseded historical maximums (Figure 9).

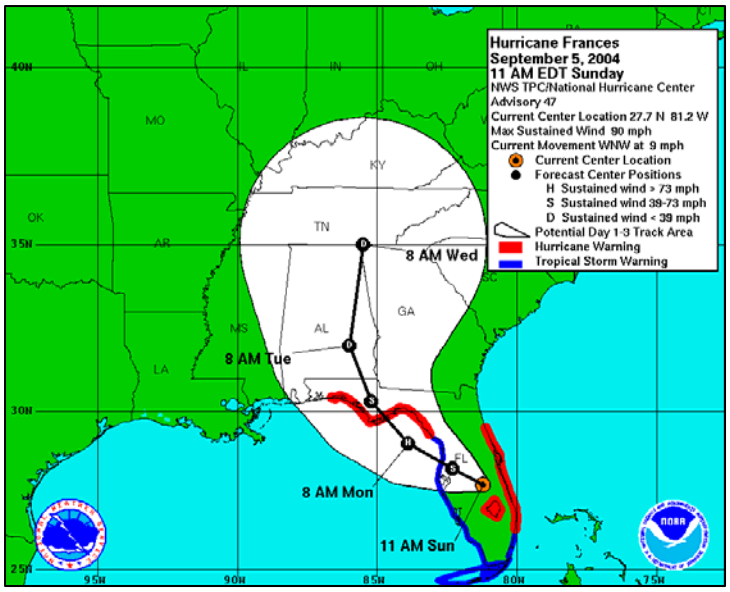


Figure 8. NHC Advisory Graphic 47.

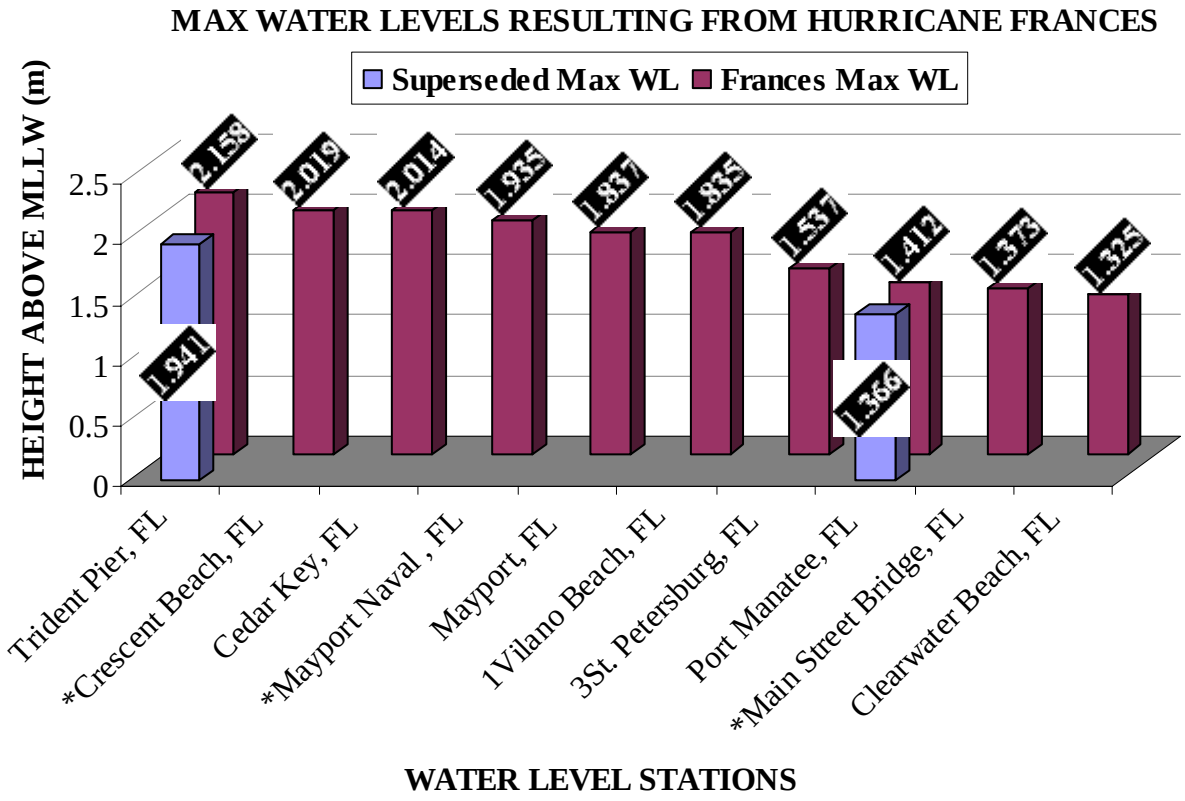


Figure 9. The maximum water levels recorded during Hurricane Frances. Trident Pier and Port Manatee maximum water levels superseded historical maximums. Notes: (*) Operated by the FDEP; (1) Station reached maximum sensor limits; and (3) Maximum water level was also the maximum surge value.

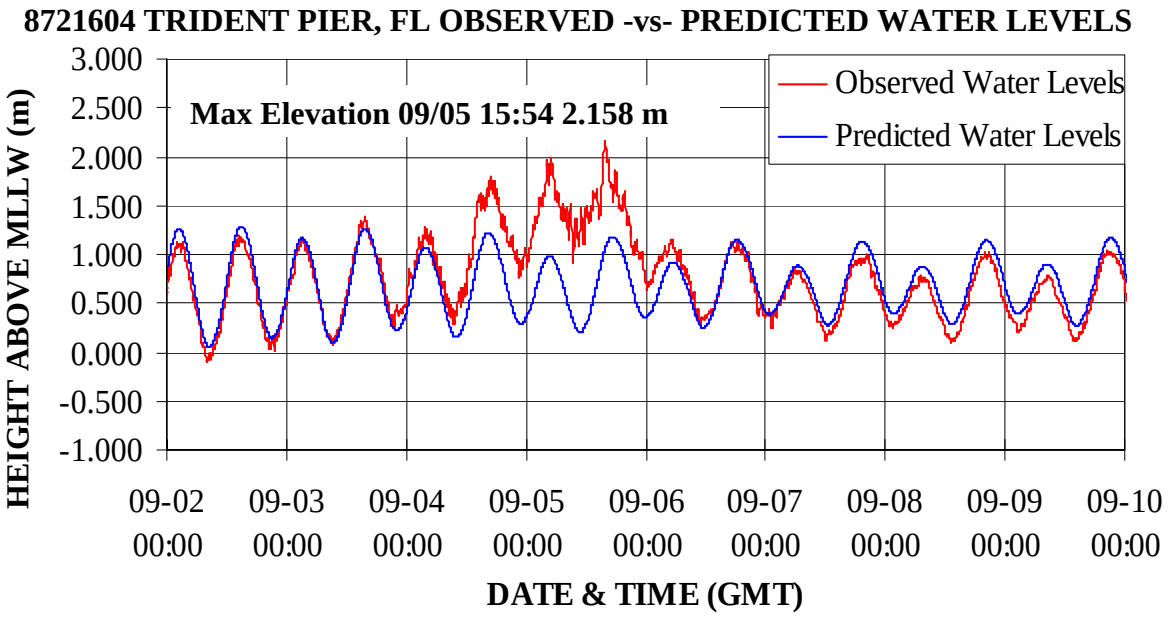


Figure 10. Time series of observed water levels and predicted tides for Trident Pier, FL.

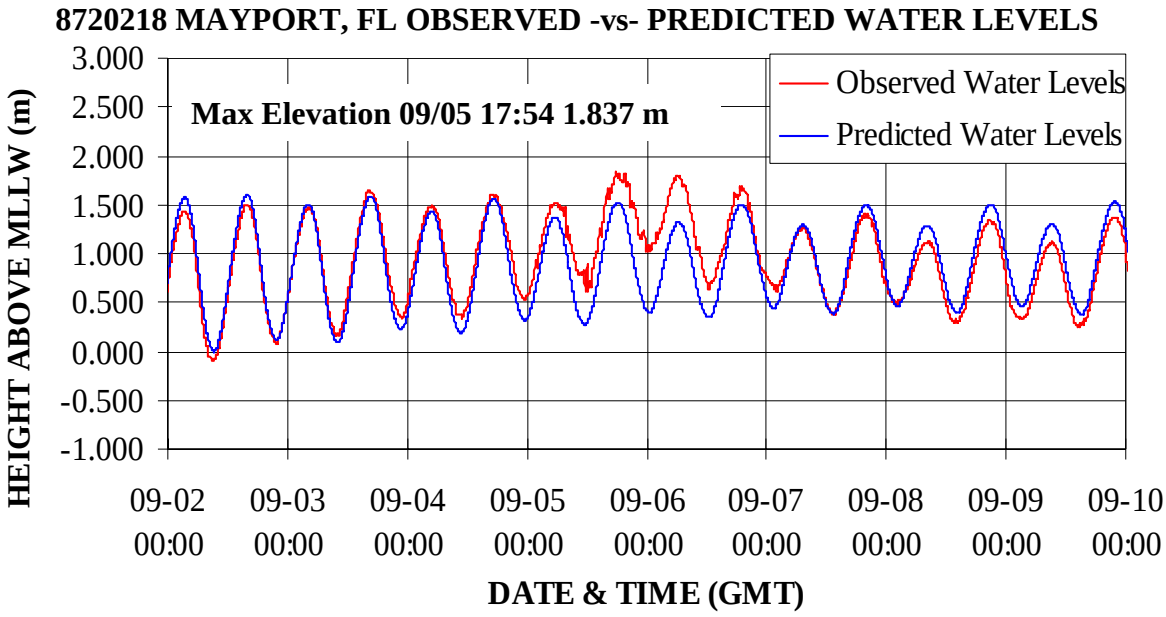


Figure 11. Time series of observed water levels and predicted tides for Mayport, FL.

In the same time frame, many of the west coast stations were experiencing the lowest water levels of the storm. Cedar Key, St. Petersburg, Apalachicola and Clearwater Beach had water levels ranging from -0.850 to 0.033 m above MLLW (Figure 12).

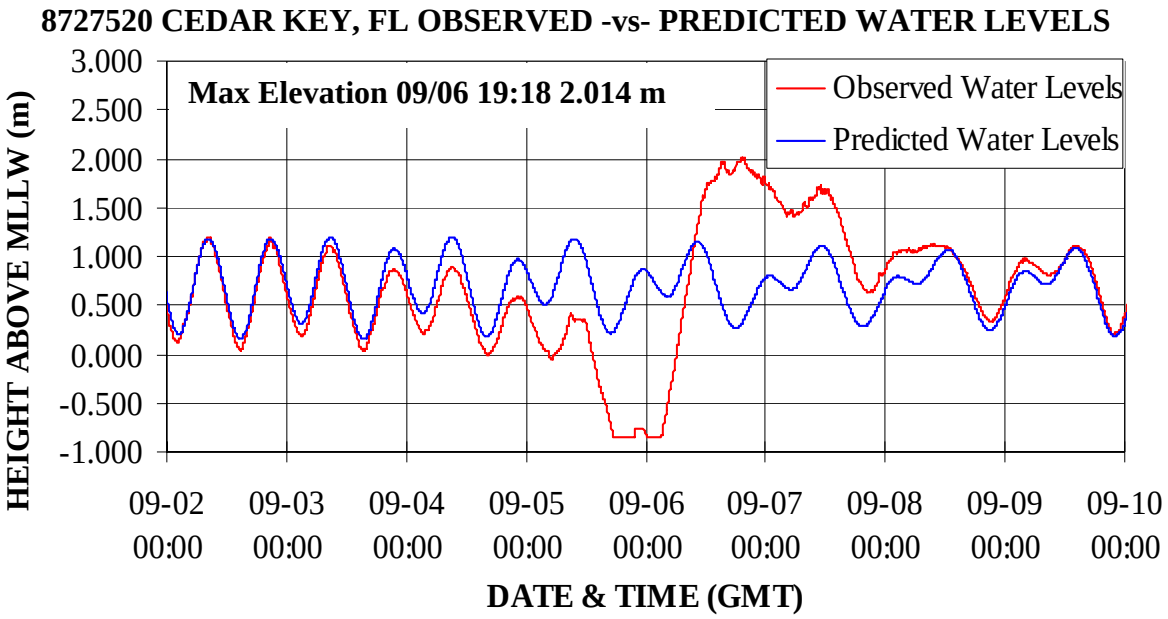


Figure 12. Time series of observed water levels and predicted tides for Cedar Key, FL. Note: Station reached minimum sensor limits.

By 1700 EDT/ 2100Z on Sunday, September 5, Frances had downsized to a Tropical Storm. At 2300 EDT/ 0300Z, Frances was on the western coastline (Figure 13).

Monday, September 6

During late Sunday night and early Monday morning, the St. Johns River experienced the maximum water levels, initially near the headwaters at Buffalo Bluff and Palatka, then successively from the Main Street Bridge to Racy Point (Table 3). Water levels ranged from 0.975 m to 0.373 m above MLLW. This coincided with maximum precipitation, from 2-9 inches in that area (Figure 15).

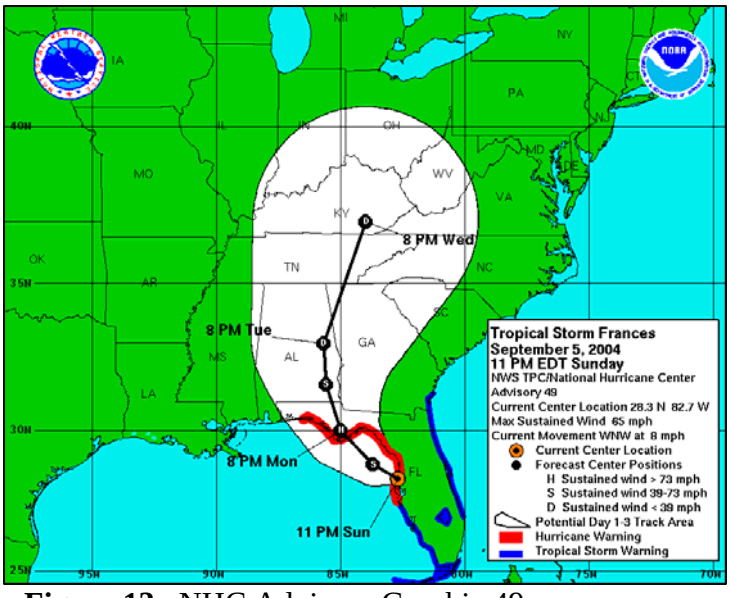


Figure 13. NHC Advisory Graphic 49.

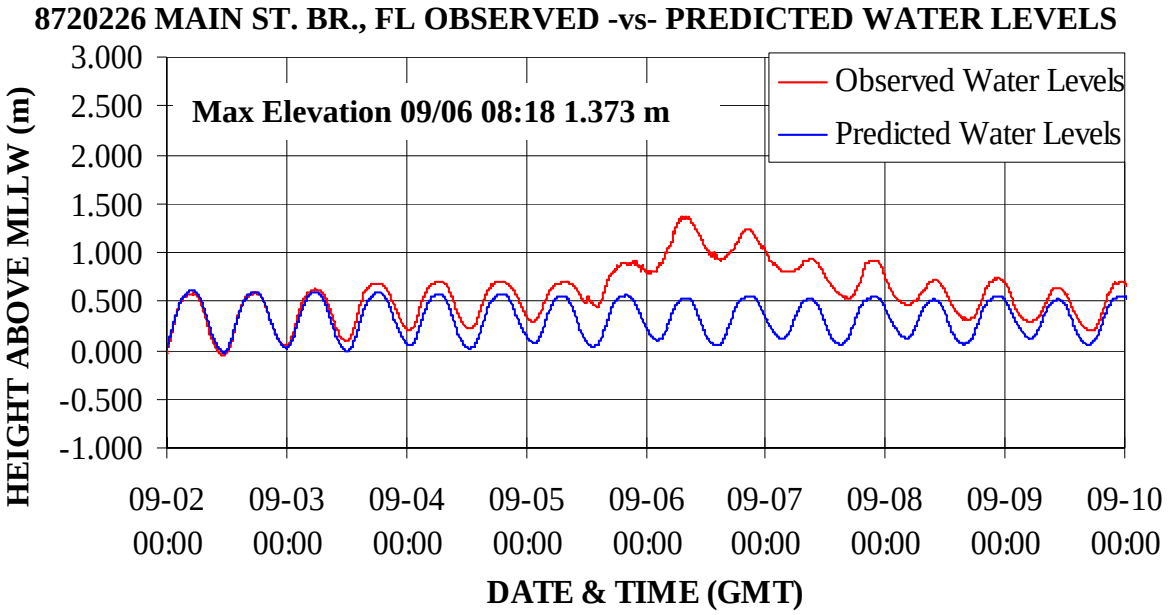


Figure 14. Time series of observed water levels and predicted tides for Main Street Bridge, St. Johns River, FL.

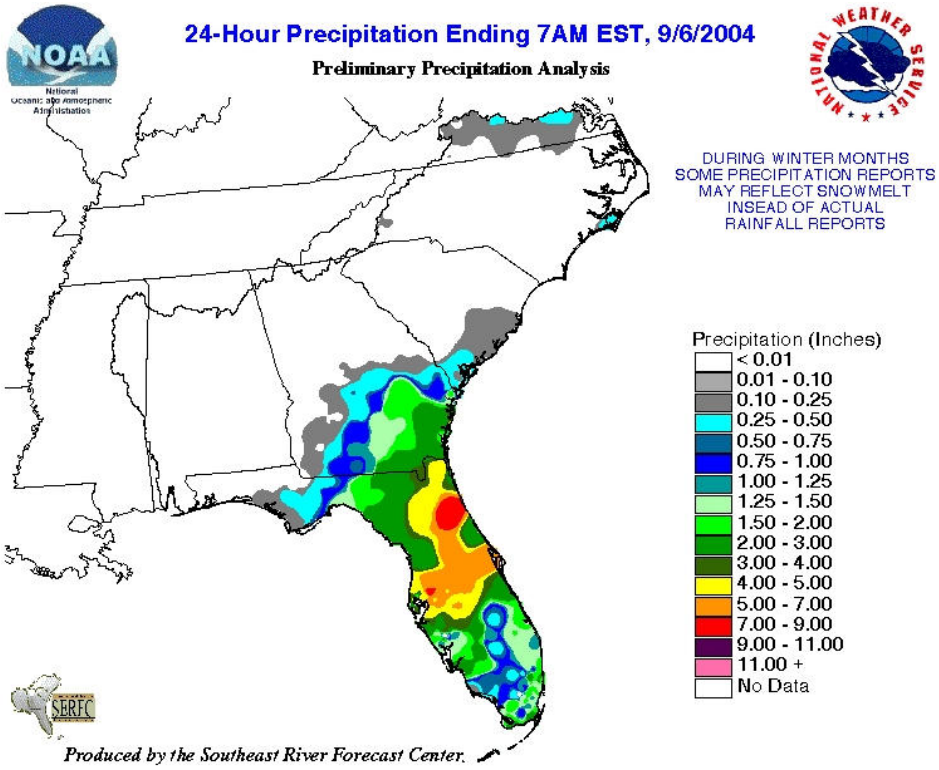


Figure 15. Southeast River Forecast Center (SERFC) Preliminary Precipitation Analysis (Courtesy of SEFRC).

In the early morning hours of Monday, when the final impacts were occurring on the east coast, the west coast began to experience maximum water levels (Figure 16). Naples was the first station (1.312 m, 0806Z), followed by Fort Myers (1.221m, 1100Z), Clearwater Beach (1.325 m, 1142Z) and Port Manatee (1.412 m, 1300Z). Water was flowing back into the Gulf of Mexico, including stations that had experienced receding water levels, such as St. Petersburg and Cedar Key. St. Petersburg reached the maximum at 1448Z (1.537 m) and has the distinction of being the only station in Florida whose maximum water level also coincided with maximum storm surge (Figure 17). In addition, the timing also coincided with a high tide period, for even higher water elevations.

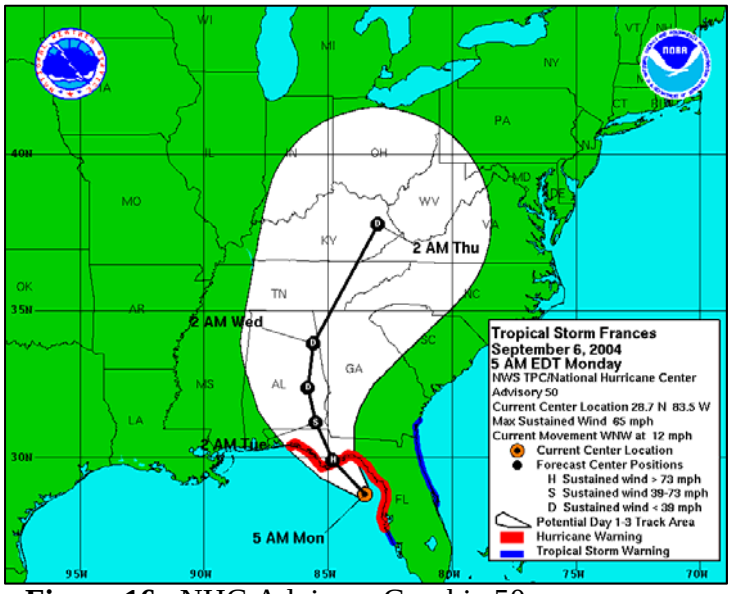


Figure 16. NHC Advisory Graphic 50.

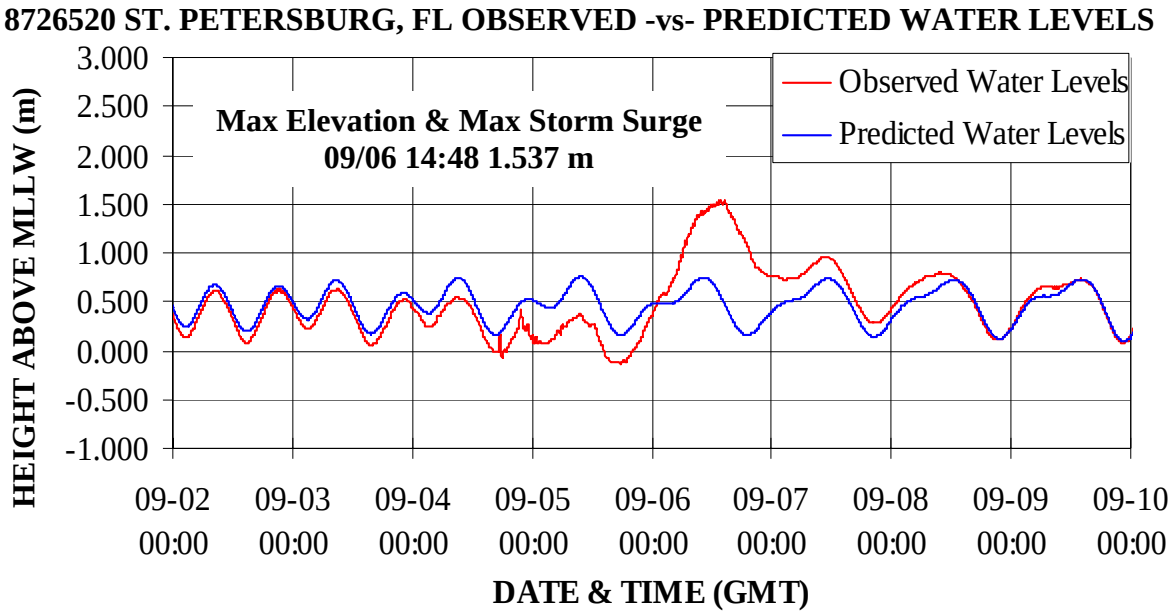


Figure 17. Time series of observed water levels and predicted tides for St Petersburg, FL.

Frances made landfall on the Florida Panhandle on Monday, September 6, at 1400 EDT/ 1800Z. Soon after, Cedar Key experienced maximum water levels (2.014 m, 1918Z; Figure 12). By 1700 EDT/ 2100Z, Frances was located 75 miles northeast of Apalachicola, Florida (30.6^{o} N, 84.3^{o} W; Figure 18). Maximum sustained winds were around 45 mph with higher gusts over the water. Minimum water levels were recorded at Pensacola, Florida (-0.214 m, 2112Z) and Dauphin Island, Alabama (-0.187 m, 2130Z). The National Hurricane Center issued the last public advisory at 2300 EDT/ 0300Z after Frances weakened into a Tropical Depression.

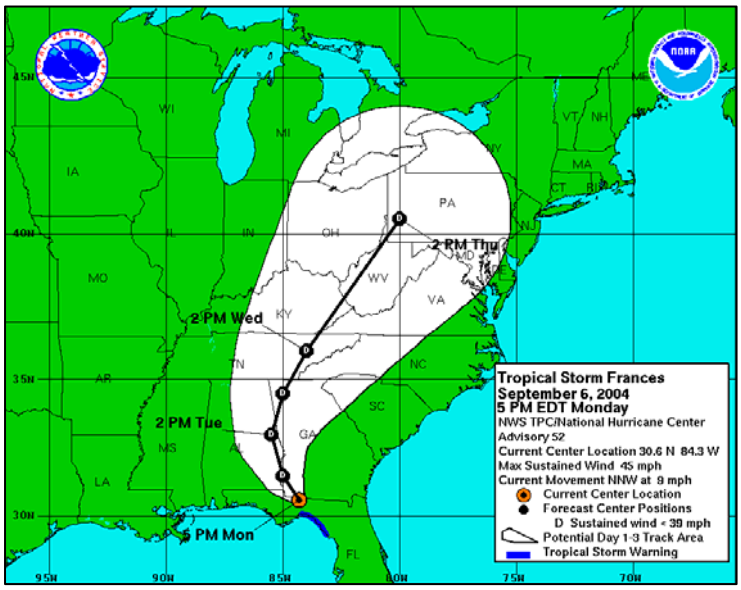


Figure 18. NHC Advisory Graphic 52.

Stations in the panhandle, continued to return to normal late Monday night and early Tuesday morning. Pensacola, Dauphin Island, Panama City and Panama City Beach eventually returned to normal after the minimum water levels and did not experience any heightened water levels as a result of Frances. However, Tuesday morning, Apalachicola continued to rise until 1054Z when the maximum water level reached 0.756 m above MLLW.

Storm Surge Analysis

The primary physical components of storm surge are 1) water level elevation due to wind stress produced by a storm, mainly manifested as water pushed toward the shore, and 2) water level elevation due to diminished atmospheric pressure within the storm. Other factors, including the location of the station with respect to the track of the storm, the local orientation of the coastline with respect to the direction of the prevailing winds and the storm's strength and speed all contribute to the height and timing of the storm surge. The height of the storm surge, for CO-OPS mission purposes, is computed simply as *the difference between the observed water level and the predicted tide level*.

Maximum storm surges are displayed in geographical order (Table 4). Seven of the highest storm surge values are displayed in Figure 19. Of these stations, four were also among the highest maximum water levels, including Cedar Key, Trident Pier, St. Petersburg and Crescent Beach. The timing of the maximum water levels coincided with the maximum storm surge at one station in Florida, St. Petersburg and at two of the three Puerto Rican stations, Magueyes Island and Punta Guayanilla. In all cases, the timing coincided with a high tide period, for even higher water elevations.

Table 4. By geographical order, the maximum storm surge (observed - predicted) data for Hurricane Frances relative to MLLW. Minimum (shaded values) water levels are included for stations that experienced receded water levels.

*Operated by FDEP.
[1]Stations whose data flatlined at the maximum water level due to reaching sensor maximum
[2]Stations whose data flatlined at the minimum water levels due to reaching sensor minimum
[3]Stations where the maximum storm surge value is also the maximum water level value.

*For the purpose of timely release, data contained within this report have undergone "limited" NOS Quality Assurance/Control; however, the data have not yet undergone final verification. All data subject to NOS verification.

Station Name	Station ID	Date/Time (EDT)	Date/Time (GMT/Z)	Elevation above: MLLW		
				Observed	Predicted	Surge
Mayport, FL	8720218	09/05/04 19:24	09/05/04 23:24	1.225	0.475	0.750
*Mayport Naval , FL	8720211	09/05/04 19:24	09/05/04 23:24	1.208	0.326	0.882
[1]Vilano Beach, FL	8720554	09/05/04 21:00	09/06/04 01:00	1.187	0.276	0.911
*Crescent Beach, FL	8720651	09/05/04 20:54	09/06/04 00:54	1.369	0.286	1.083
*Bings Landing, FL	8720757	09/05/04 22:18	09/06/04 02:18	1.151	0.400	0.751
*Main Street Bridge, FL	8720226	09/06/04 09:42	09/06/04 13:42	0.993	0.069	0.924
*I-295 Bridge, FL	8720357	09/06/04 10:06	09/06/04 14:06	0.953	0.032	0.921
*Red Bay Point, FL	8720503	09/06/04 11:06	09/06/04 15:06	0.873	0.067	0.806
Racy Point, FL	8720625	09/06/04 00:12	09/06/04 04:12	0.820	0.145	0.675
[1]*Palatka, FL	8720774	09/06/04 00:06	09/06/04 04:06	0.986	0.464	0.522
*Buffalo Bluff, FL	8720767	09/06/04 00:42	09/06/04 04:42	0.963	0.439	0.524
Trident Pier, FL	8721604	09/05/04 07:06	09/05/04 11:06	1.479	0.209	1.270
Virginia Key, FL	8723214	09/05/04 11:00	09/05/04 15:00	0.670	0.354	0.316
Vaca Key, FL	8723970	09/05/04 01:06	09/05/04 05:06	0.622	0.261	0.361
Key West, FL	8724580	09/05/04 07:48	09/05/04 11:48	0.318	0.174	0.144
Naples, FL	8725110	09/05/04 13:18	09/05/04 17:18	0.912	0.280	0.632
Fort Myers, FL	8725520	09/04/04 23:12	09/05/04 03:12	0.036	0.254	-0.218
Fort Myers, FL	8725520	09/06/04 05:06	09/06/04 09:06	1.125	0.270	0.855
Port Manatee, FL	8726384	09/06/04 12:24	09/06/04 16:24	1.211	0.266	0.945
St. Petersburg, FL	8726520	09/05/04 06:42	09/05/04 10:42	0.280	0.736	-0.456
[3]St. Petersburg, FL	8726520	09/06/04 10:48	09/06/04 14:48	1.537	0.453	1.084
Clearwater Beach, FL	8726724	09/05/04 15:12	09/05/04 19:12	0.134	0.508	-0.374
Clearwater Beach, FL	8726724	09/06/04 11:24	09/06/04 15:24	1.118	0.276	0.842
Cedar Key, FL	8727520	09/06/04 14:30	09/06/04 18:30	1.974	0.269	1.705
[2]Cedar Key, FL	8727520	09/05/04 20:06	09/06/04 00:06	-0.841	0.855	-1.696
Apalachicola, FL	8728690	09/07/04 05:54	09/07/04 09:54	0.753	0.504	0.249
[2]Apalachicola, FL	8728690	09/06/04 07:42	09/06/04 11:42	-0.058	0.568	-0.626
Panama City, FL	8729108	09/07/04 03:30	09/07/04 07:30	-0.035	0.503	-0.538
Panama City Beach, FL	8729210	09/05/04 20:18	09/06/04 00:18	-0.335	0.318	-0.653
Pensacola, FL	8729840	09/06/04 04:42	09/06/04 08:42	0.194	0.516	-0.322
Dauphin Island , AL	8735180	09/07/04 03:54	09/07/04 07:54	0.149	0.471	-0.322
Lime Tree Bay, VI	9751401	08/31/04 14:30	08/31/04 18:30	0.258	0.112	0.146
San Juan, PR	9755371	08/31/04 15:18	08/31/04 19:18	0.307	0.11	0.197
Charlotte Amalie, VI	9751639	09/01/04 14:36	09/01/04 18:36	0.237	0.123	0.114
[3]Punta Guayanilla, PR	9758053	09/03/04 16:24	09/03/04 20:24	0.361	0.234	0.127
[3]Magueyes Island, PR	9759110	09/03/04 17:18	09/03/04 21:18	0.351	0.209	0.142

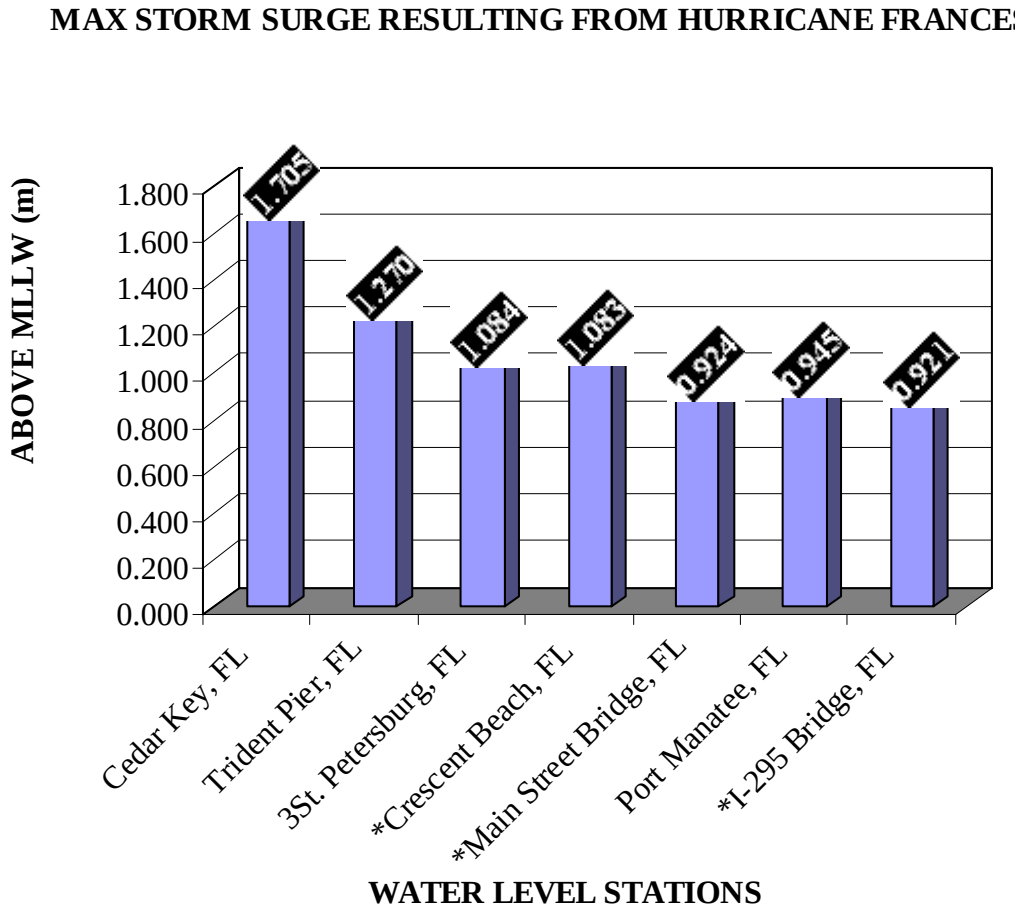


Figure 19. The maximum storm surge recorded during Hurricane Frances. Notes: (*) Operated by the FDEP; and (3) Maximum surge value was also the maximum water level.

Appendix

Station Name	Station ID	Latitude	Longitude
Mayport, FL	8720218	30° 23.8' N	81° 25.8' W
*Mayport Naval , FL	8720211	30° 24.0' N	81° 24.8' W
Vilano Beach, FL	8720554	29° 55.0' N	81° 18.0' W
*Crescent Beach, FL	8720651	29° 46.1' N	81° 15.5' W
*Bings Landing, FL	8720757	29° 36.9' N	81° 12.3' W
*Main Street Bridge, FL	8720226	30° 19.2' N	81° 39.5' W
*I-295 Bridge, FL	8720357	30° 11.5' N	81° 41.5' W
*Red Bay Point, FL	8720503	29° 58.7' N	81° 37.7' W
Racy Point, FL	8720625	29° 48.1' N	81° 32.9' W
*Palatka, FL	8720774	29° 38.6' N	81° 37.9' W
*Buffalo Bluff, FL	8720767	29° 35.7' N	81° 40.9' W
Trident Pier, FL	8721604	28° 24.9' N	80° 35.6' W
Virginia Key, FL	8723214	25° 43.9' N	80° 09.7' W
Vaca Key, FL	8723970	24° 42.7' N	81° 06.3' W
Key West, FL	8724580	24° 33.2' N	81° 48.5' W
Naples, FL	8725110	26° 07.8' N	81° 48.4' W
Fort Myers, FL	8725520	26° 38.8' N	81° 52.3' W
Port Manatee, FL	8726384	27° 38.2' N	82° 33.8' W
St. Petersburg, FL	8726520	27° 45.6' N	82° 37.6' W
Clearwater Beach, FL	8726724	27° 58.6' N	82° 49.9' W
Cedar Key, FL	8727520	29° 08.1' N	83° 01.9' W
Apalachicola, FL	8728690	29° 43.6' N	84° 58.9' W
Panama City, FL	8729108	30° 09.1' N	85° 40.0' W
Panama City Beach, FL	8729210	30° 12.8' N	85° 52.8' W
Pensacola, FL	8729840	30° 24.2' N	87° 12.7' W
Dauphin Island , AL	8735180	30° 15.0' N	88° 04.5' W
Lime Tree Bay, VI	9751401	17° 41.8' N	64° 45.2' W
Charlotte Amalie, VI	9751639	18° 20.1' N	64° 55.2' W
San Juan, PR	9755371	18° 27.5' N	66° 07.0' W
Punta Guayanilla, PR	9758053	17° 58.6' N	66° 45.7' W
Magueyes Island, PR	9759110	17° 58.6' N	67° 02.8' W

*Operated by FDEP

Appendix 2

Excerpt From:

Tide and Current Glossary, NOAA National Ocean Service, Silver Spring, MD, 2000.

tide: The periodic rise and fall of a body of water resulting from gravitational interactions between Sun, Moon, and Earth. The vertical component of the particulate motion of a tidal wave. Although the accompanying horizontal movement of the water is part of the same phenomenon, it is preferable to designate this motion as tidal current. Same as astronomic tide.

tide (water level) gauge: An instrument for measuring the rise and fall of the tide (water level).

storm tide: As used by the National Weather Service, NOAA, the sum of the storm surge and astronomic tide. See storm surge and tide.

storm surge: The local change in the elevation of the ocean along a shore due to a storm. The storm surge is measured by subtracting the astronomic tidal elevation from the total elevation. It typically has a duration of a few hours. Since wind generated waves ride on top of the storm surge (and are not included in the definition), the total instantaneous elevation may greatly exceed the predicted storm surge plus astronomic tide. It is potentially catastrophic, especially on low lying coasts with gently sloping offshore topography. See storm tide.

National Water Level Observation Network (NWLON): The network of tide and water level stations operated by the National Ocean Service along the marine and Great Lakes coasts and islands of the United States.

datum (vertical): For marine applications, a base elevation used as a reference from which to reckon heights or depths. It is called a tidal datum when defined in terms of a certain phase of the tide. Tidal datums are local datums and should not be extended into areas which have differing hydrographic characteristics without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points known as bench marks. See chart datum and bench marks.

chart datum: The datum to which soundings on a chart are referred. It is usually taken to correspond to a low-water elevation, and its depression below mean sea level is represented by the symbol Z_o. Since 1980, chart datum has been implemented to mean lower low water for all marine waters of the United States, its territories, Commonwealth of Puerto Rico, and Trust Territory of the Pacific Islands. See datum and National Tidal Datum Convention of 1980.

geodetic datum: See National Geodetic Vertical Datum of 1929 (NGVD 1929) and North American Vertical Datum of 1988 (NAVD 1988).

Mean Lower Low Water (MLLW): A tidal datum. The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. See National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.

National Tidal Datum Epoch: The specific l9-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present National Tidal Datum Epoch is 1960 through 1978. It is reviewed annually for possible revision and must be actively considered for revision every 25 years.

National Tidal Datum Convention of 1980: Effective November 28, 1980, the Convention: (1) establishes one uniform, continuous tidal datum system for all marine waters of the United States, its territories, Commonwealth of Puerto Rico, and Trust Territory of the Pacific Islands, for the first time in history; (2) provides a tidal datum system independent of computations based on type of tide; (3) lowers chart datum from mean low water to mean lower low water along the Atlantic coast of the United States; (4) updates the National Tidal Datum Epoch from 1941 through 1959, to 1960 through 1978; (5) changes the name Gulf Coast Low Water Datum to mean lower low water; (6) introduces the tidal datum of mean higher high water in areas of predominantly diurnal tides; and (7) lowers mean high water in areas of predominantly diurnal tides. See chart datum.

National Geodetic Vertical Datum of 1929 [NGVD 1929]: A fixed reference adopted as a standard geodetic datum for elevations determined by leveling. The datum was derived for surveys from a general adjustment of the first-order leveling nets of both the United States and Canada. In the adjustment, mean sea level was held fixed as observed at 21 tide stations in the United States and 5 in Canada. The year indicates the time of the general adjustment. A synonym for Sea-level Datum of 1929. The geodetic datum is fixed and does not take into account the changing stands of sea level. Because there are many variables affecting sea level, and because the geodetic datum represents a best fit over a broad area, the relationship between the geodetic datum and local mean sea level is not consistent from one location to another in either time or space. For this reason, the National Geodetic Vertical Datum should not be confused with mean sea level. See North American Vertical Datum of 1988 (NAVD 1988).

North American Vertical Datum of 1988 [NAVD 1988]: A fixed reference for elevations determined by geodetic leveling. The datum was derived from a general adjustment of the first-order terrestrial leveling nets of the United States, Canada, and Mexico. In the adjustment, only the height of the primary tidal bench mark, referenced to the International Great Lakes Datum of 1985 (IGLD 1985) local mean sea level height value, at Father Point, Rimouski, Quebec, Canada was held fixed, thus providing minimum constraint. NAVD 1988 and IGLD 1985 are identical. However, NAVD 1988 bench mark values are given in Helmert orthometric height units while IGLD 1985 values are in dynamic heights. See International Great Lakes Datum of 1985, National Geodetic Vertical Datum of 1929, and geopotential difference.

bench mark (BM): A fixed physical object or mark used as reference for a horizontal or vertical datum. A tidal bench mark is one near a tide station to which the tide staff and tidal

datums are referred. A primary bench mark is the principal mark of a group of tidal bench marks to which the tide staff and tidal datums are referred.

For further information on tides, tidal predictions, tidal datums and related publications, contact:

NOAA, National Ocean Service
CO-OPS, Products and Services N/OPS3
Attn: User Services
1305 East-West Highway
Silver Spring, MD 20190-3281

(301) 713-2877 Ext. 176
Fax: (301) 713-4437