

HURRICANE IVAN CHARACTERISTICS and STORM TIDE EVALUATION

By

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I. Synoptic History

Hurricane Ivan developed from a large tropical wave that moved off the west coast of Africa on 31 August, 2004. It continued to develop to a tropical depression around 1800 UTC 2 September and became Tropical Storm Ivan at 0600 UTC 3 September. Ivan continued on a generally westward motion and steadily strengthened, becoming a hurricane at 0600 UTC 5 September. Ivan reached the Category 5 strength 3 times in Caribbean Sea before it entered the Gulf of Mexico early on 14 September at Category 4 strength (Figure 1).

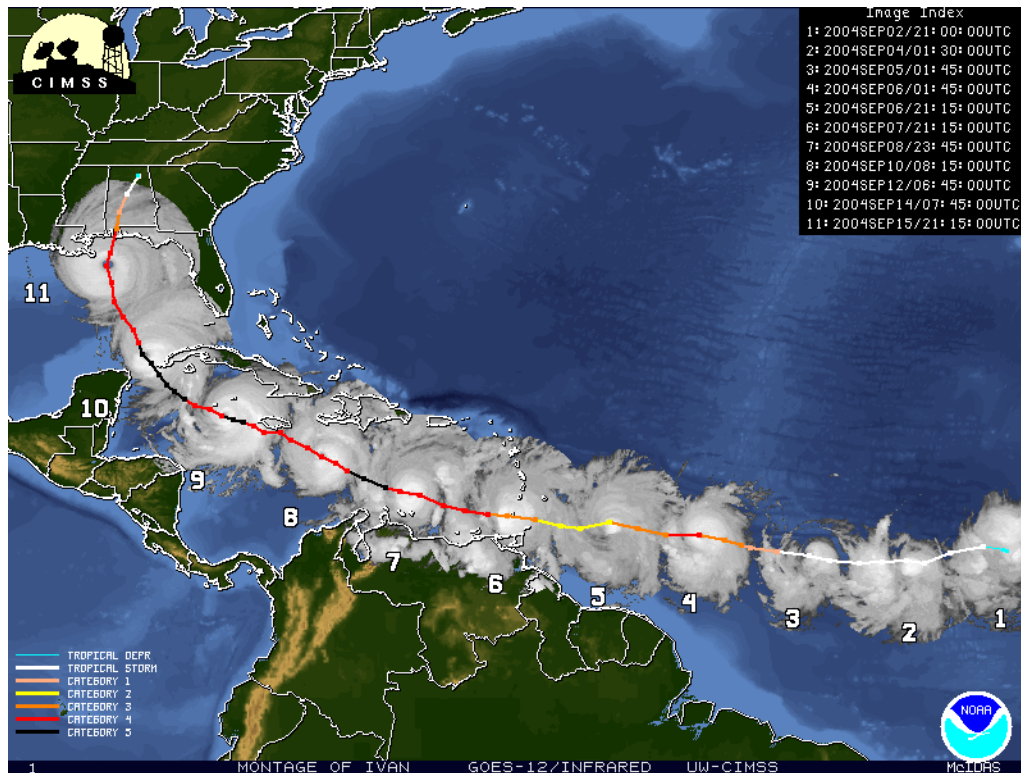


Figure 1. Hurricane Ivan track (Source: CIMSS, UW - Madison).

As Ivan neared the northern U.S. Gulf coast, it weakened only slowly and made landfall as a 121 m.p.h. hurricane (Category 3) at approximately 1:50 a.m. CDT (0650 UTC) 16 September, just west of Gulf Shores, Alabama (Figure 2). By this time, the eye diameter had increased to 40-50 n mi. (Figure 3), which resulted in some of the strongest winds occurring over a narrow area near the south Alabama-western Florida panhandle border. The winds of Ivan is presented in the wind swath map show in Figure 4. The data was prepared and provided by the Hurricane Research Division (HRD) at the Atlantic Oceanographic and Meteorological Laboratory (AOML) of the National Oceanographic and Atmospheric Administration.

The graph given in Figure 5 depicts the best track central barometric pressure and wind speed history for Ivan based on data obtained from Tropical Cyclone Report of Hurricane Ivan, National Hurricane Center (Stewart, 2005). Wind speed dropped and central pressure rose dramatically right after landfall.

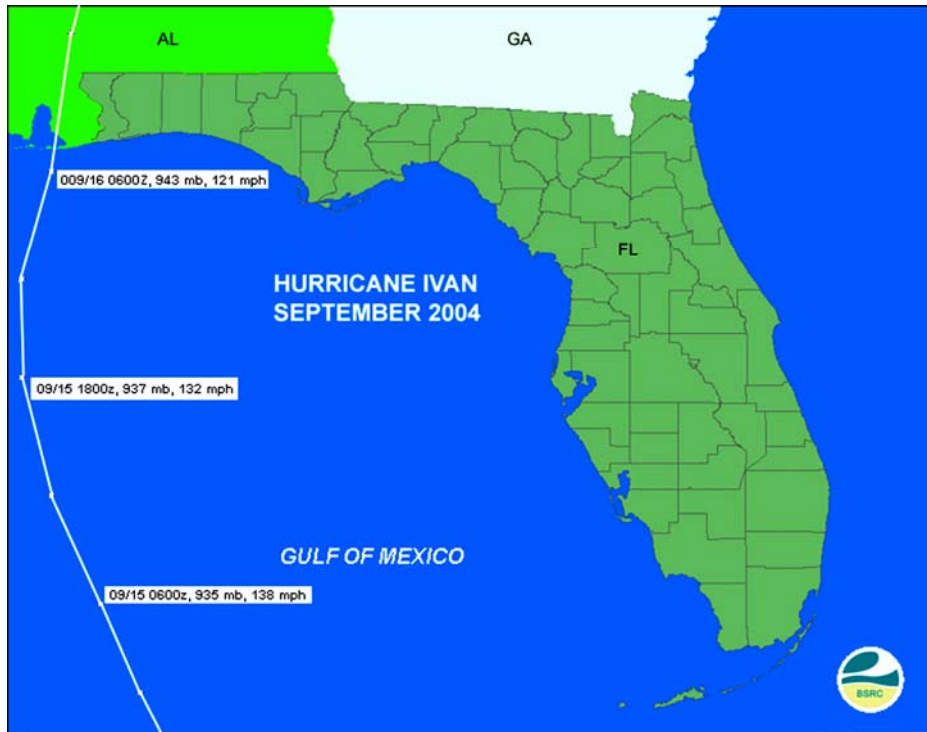


Figure 2. Hurricane Ivan track near the Gulf Coast.

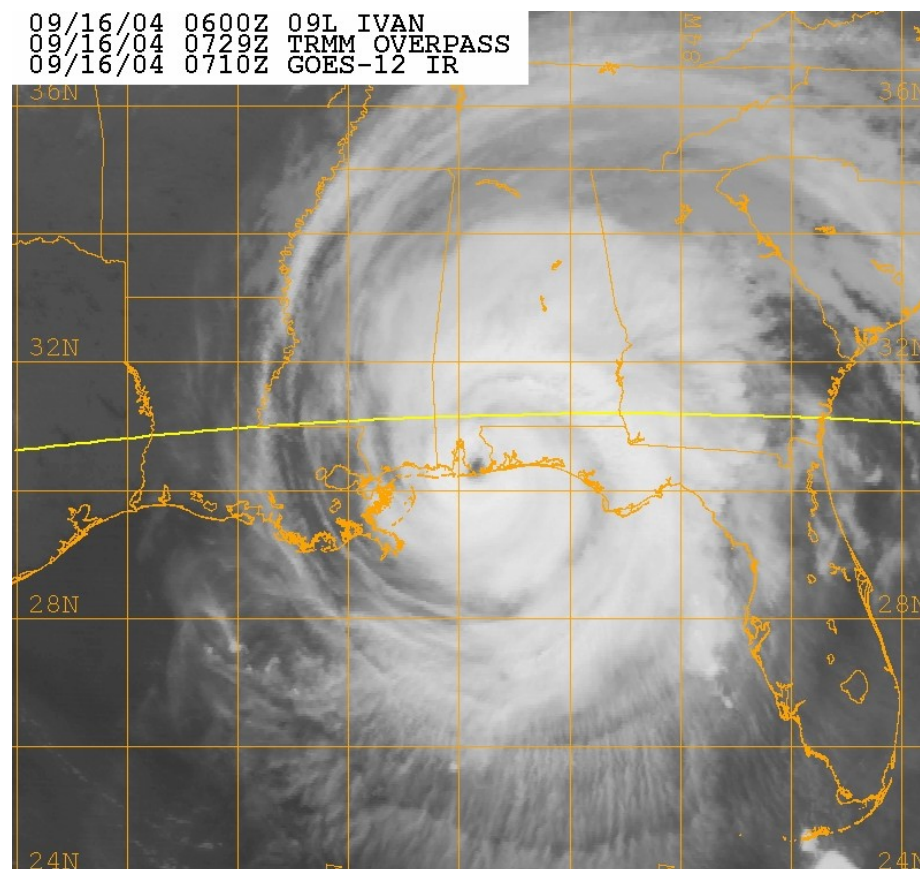


Figure 3. Eye of Hurricane Ivan at landfall (Source: Naval Research Laboratory).

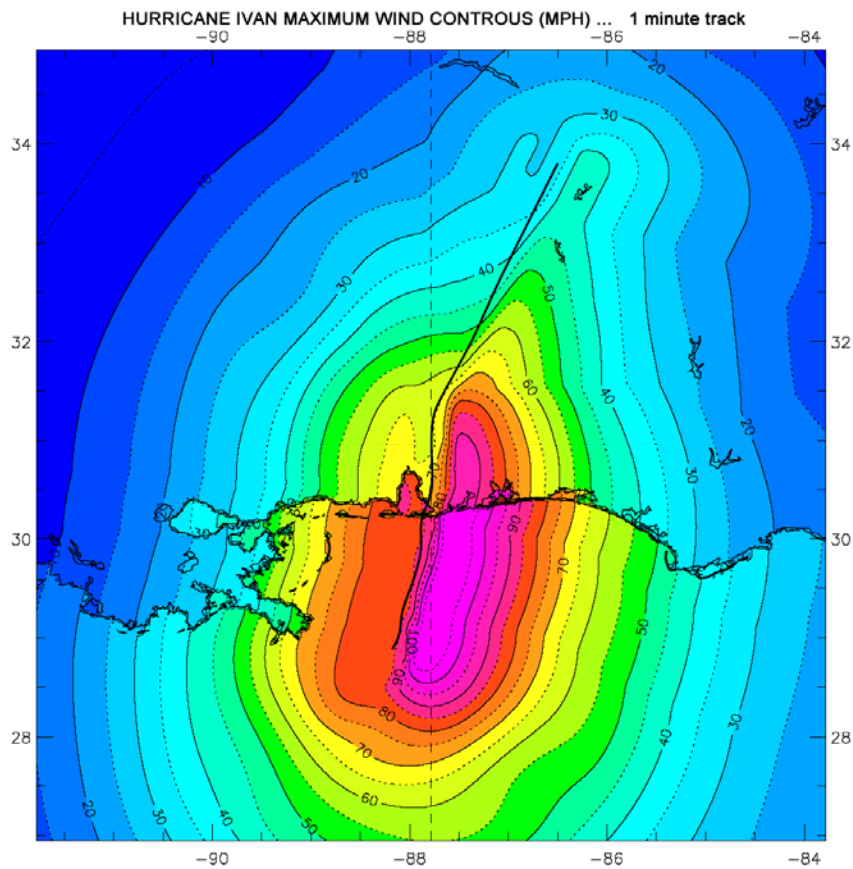


Figure 4. Surface Wind Fields Associated with Hurricane Ivan at landfall.

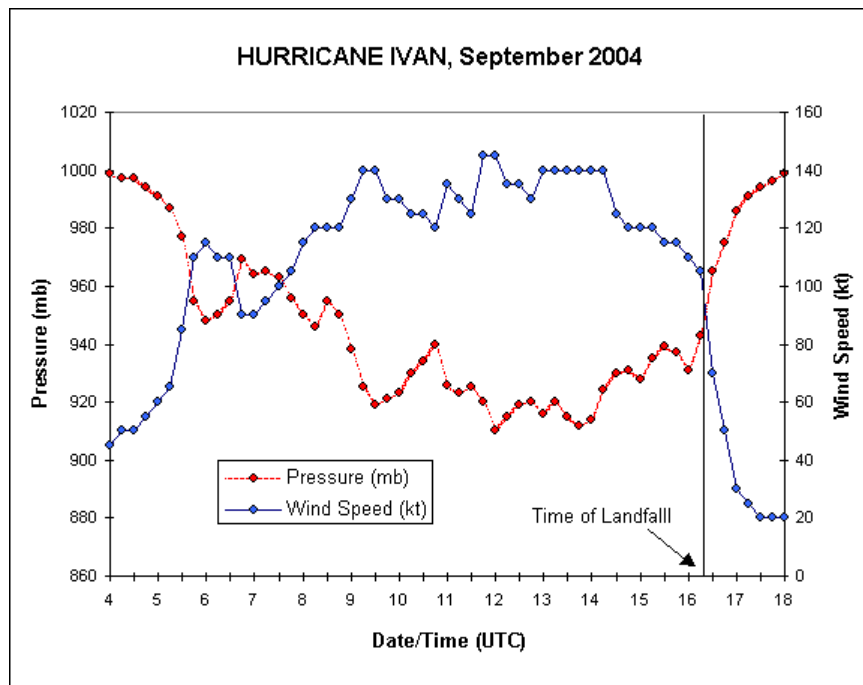


Figure 5. Best track Pressure and Wind Speed for Hurricane Ivan, 4-18 September, 2004.

II. Storm Tide Records

Hurricane Ivan was one of the strongest and most destructive hurricanes to hit Florida's Panhandle coast since Hurricane Opal in 1995 and Hurricane Eloise in 1975. Beaches were eroded and structures were damaged by its more than 120 mph wind, storm surge and accompanying storm waves from the storm's landfall to eastward counties. Escambia, Santa Rosa, Okaloosa counties suffered the worst impact with progressively diminishing level of impact occurring with increasing distance of landfall extending through Walton, Bay, Gulf and Franklin counties.

URS Group, Inc. was contracted by the Federal Emergency Management Agency (FEMA) to collect and survey Coastal High Water Marks (CHWMs) in the Panhandle area. A total of 135 CHWMs were surveyed in Escambia (57), Santa Rosa (39), Okaloosa (31), Walton (3), Bay (3) and Franklin (2) counties (FEMA, 2004).

There are a limited number of NOAA tide gauges across the Panhandle area that provided direct measurements of surge elevations, however, the gauge at Pensacola failed before the peak surge developed. In addition to NOAA tide gauges, water levels were recorded on coastal gauges maintained by the U.S. Army Corps of Engineers (USACE) Mobile District Office and the U.S. Coast Guard (USCG).

For the purpose of this report, only the interior High Water Mark (HWM) data from the beach areas or flooded area with wave setup were selected to evaluate the storm tide associated with Hurricane Ivan. Table 1 lists 21 HWM data and their location descriptions which are also shown graphically in Figure 6. Figures 7, 8 and 9 give a more detailed presentation of Figure 6.

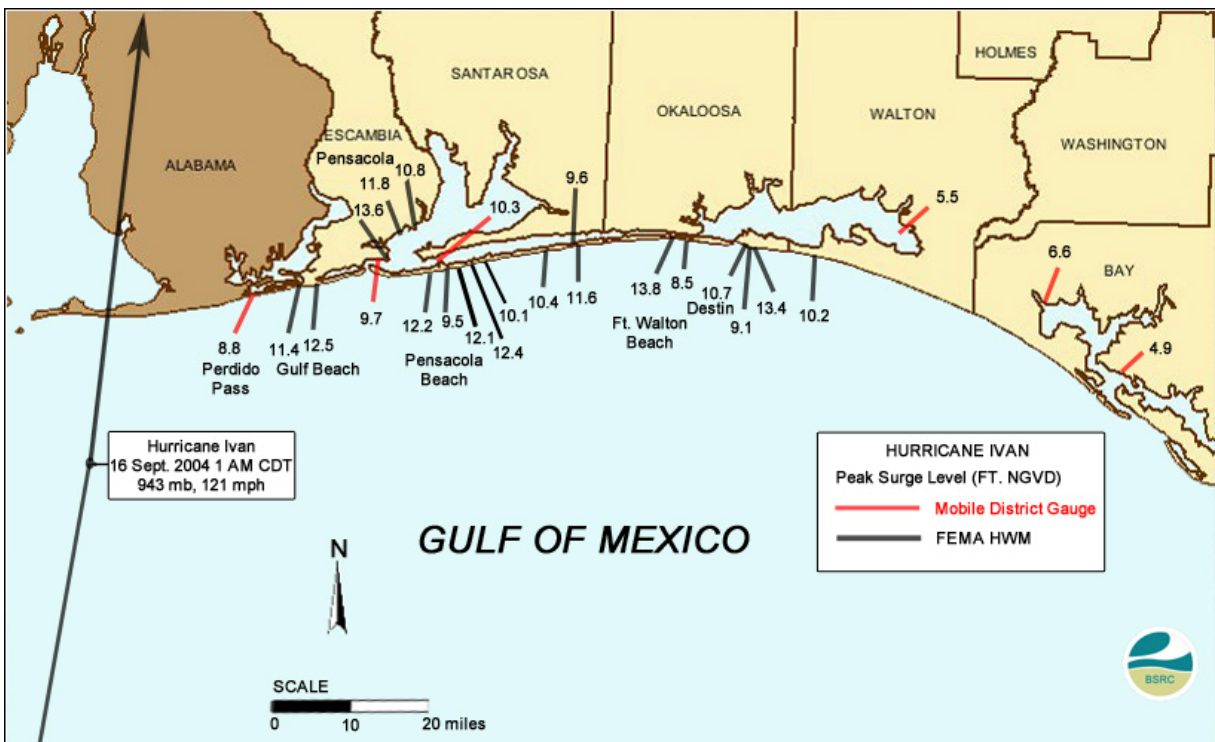


Figure 6. Surveyed Peak Surge Levels along the Panhandle area for Hurricane Ivan.

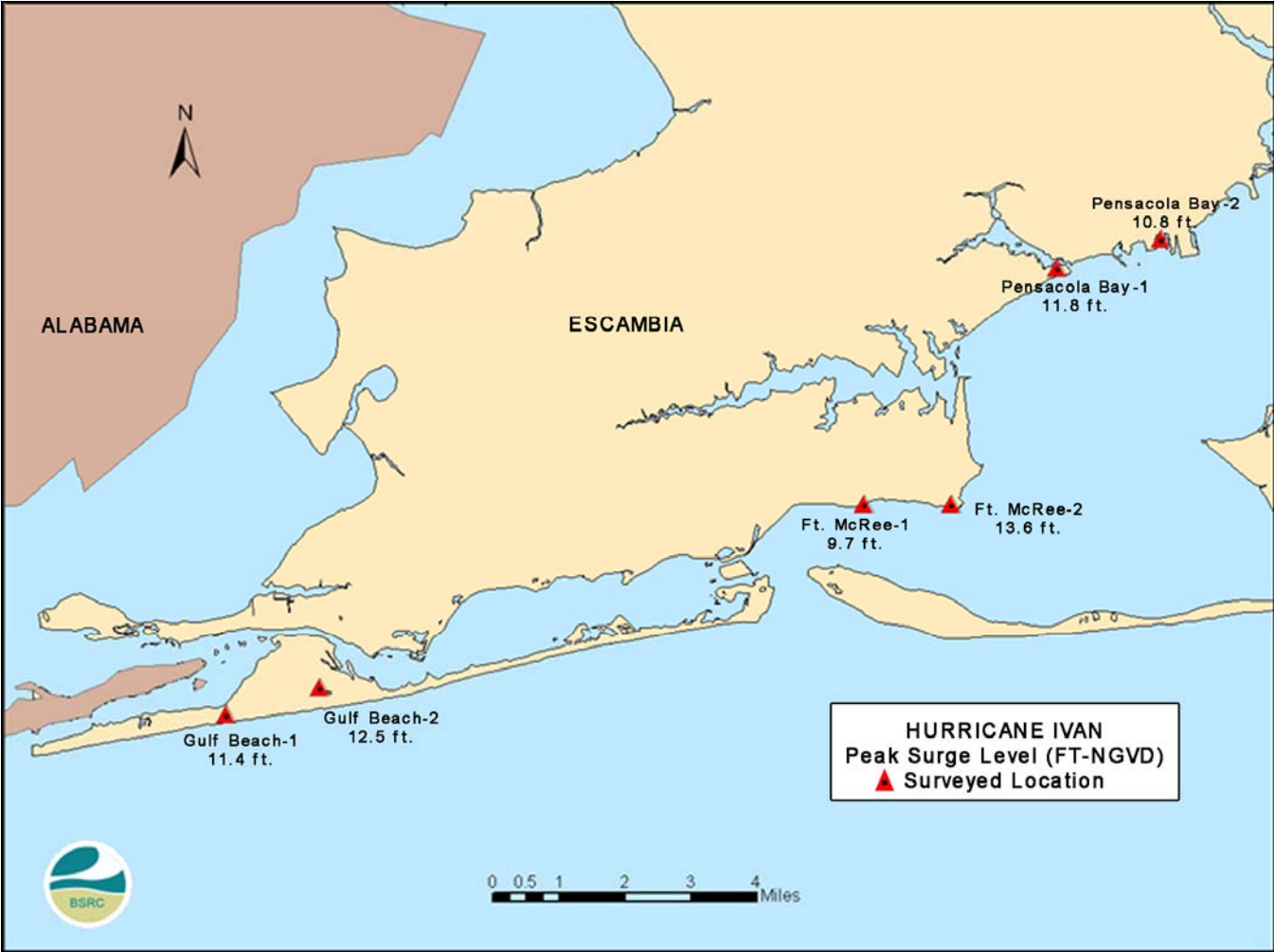


Figure 7. Surveyed Peak Surge Levels in the west Escambia County area for Hurricane Ivan.

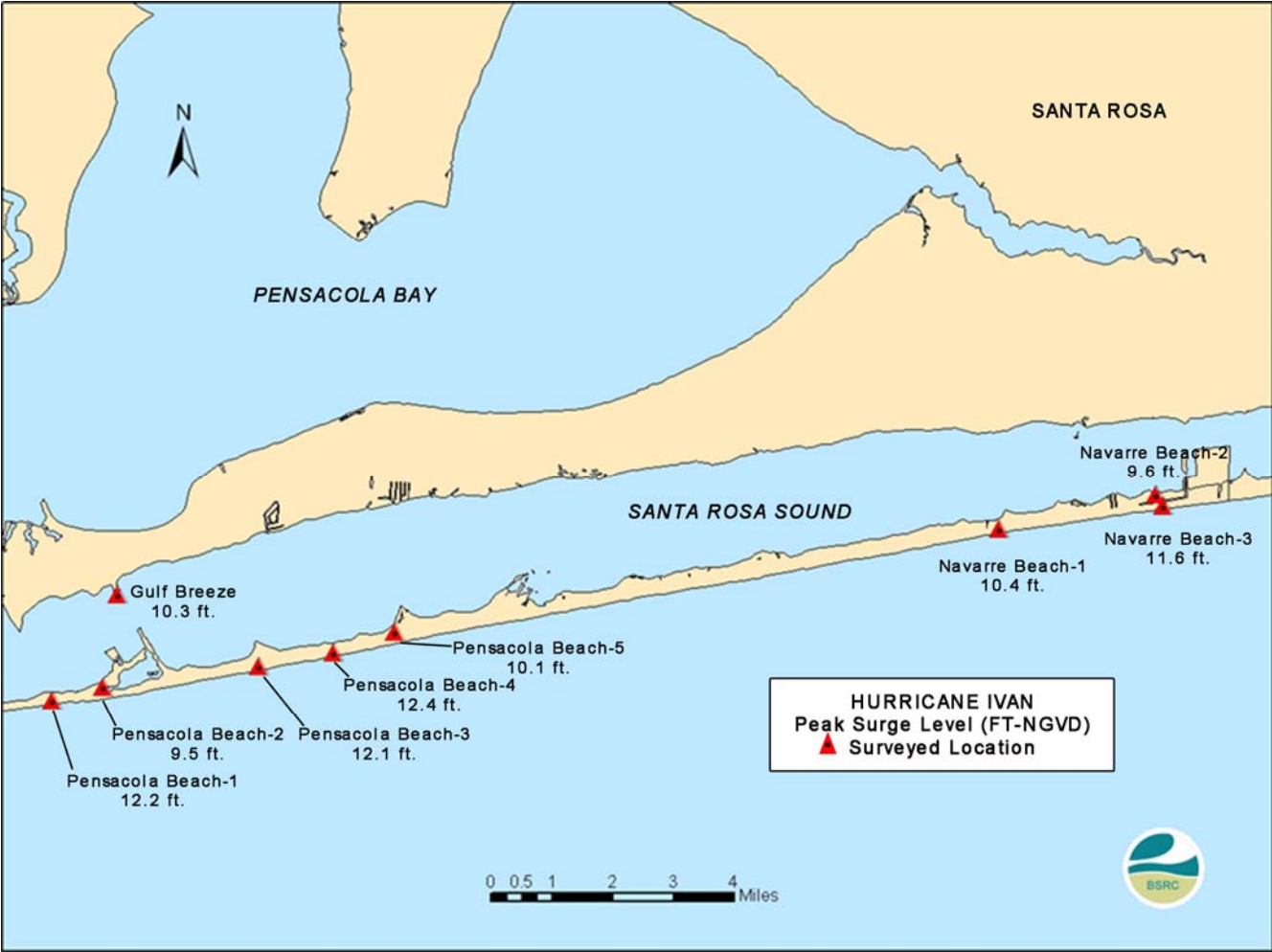


Figure 8. Surveyed Peak Surge Levels in the east Escambia County area for Hurricane Ivan.

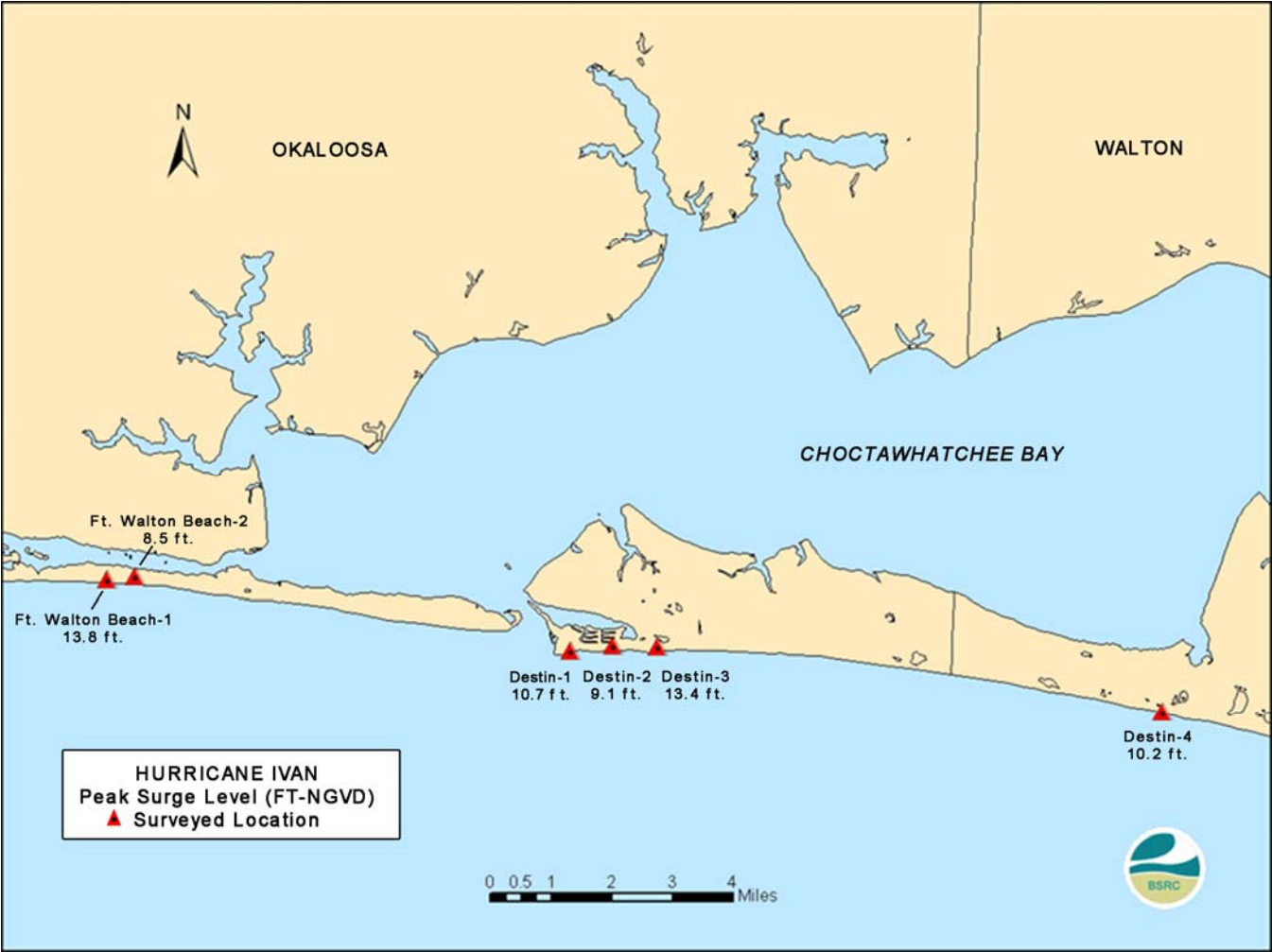


Figure 9. Surveyed Peak Surge Levels in the Okaloosa County area for Hurricane Ivan.

Table 1 High Water Marks data in the Panhandle Area during Hurricane Ivan.

Location	Peak Surge (ft-NGVD)	Position		HWM Object
		Lat.(N)	Lon.(W)	
Gulf Beach-1	11.4	30.29473	87.45055	Mud line of interior wall
Gulf Beach-2	12.5	30.30118	87.42695	Water line of interior wall
Ft. McRee-1	9.7	30.34500	87.28972	Inside HWM of USCG
Ft. McRee-2	13.6	30.34542	87.26775	Water line of interior wall
Pensacola Bay-1	11.8	30.39822	87.24213	Mud line of interior garage door
Pensacola Bay-2	10.8	30.40513	87.21600	Water line of interior door
Pensacola Beach-1	12.2	30.32670	87.17358	Mud line inside wall
Pensacola Beach-2	9.5	30.33003	87.15951	Mud line inside wall
Pensacola Beach-3	12.1	30.33601	87.11674	Water line of interior wall
Pensacola Beach-4	12.4	30.33980	87.09635	Mud line inside electric closet
Pensacola Beach-5	10.1	30.34508	87.07961	Mud line of interior hallway
Gulf Breeze	10.3	30.35222	87.15639	Inside HWM of GIWW
Navarre Beach-1	10.4	30.37305	86.91335	Mud line inside bathroom wall
Navarre Beach-2	9.6	30.38216	86.87036	Mud line inside storage area wall
Navarre Beach-3	11.6	30.37946	86.86830	Mud line of interior storage room wall
Ft. Walton Beach-1	13.8	30.39736	86.63113	Water line inside hall wall
Ft. Walton Beach-2	8.5	30.39825	86.62328	Water line inside garage door
Destin-1	10.7	30.38291	86.50265	Water line inside garage
Destin-2	9.1	30.38427	86.49094	Water line inside garage sheetrock wall
Destin-3	13.4	30.38423	86.47846	Water line inside bathroom shower wall
Destin-4	10.2	30.37097	86.33866	Water line inside door on wall

III. Storm Tide Evaluation

Interior HWM data of Table 1 shows a downward trend from about 12 feet at Gulf Beach to about 9 to 10 feet in the Destin area. Table 1 covers an area from about 27 to 92 miles east of landfall of Hurricane Ivan. Since the Radius to the Maximum Wind (RMW) of Ivan is estimated as 28 miles (Stewart, 2005). Gulf Beach and nearby areas received the worst impact by maximum wind and associated storm surge.

The general trend of the HWM data is in good agreement with the hurricane's wind distribution. Two HWM data of 13.8 feet and 13.4 feet (Ft. Walton Beach-1 and Destin-3, respectively) appear to show survey error.

To verify the surveyed HWM data, the 2-D Storm Surge Model of BSRC was employed to calculate the total storm tide (i.e. surge generated from barometric pressure and wind stress plus dynamic wave setup and astronomical tide). The 2-D grid systems and associated hydrological data of Escambia and Okaloosa counties from the CCCL study were chosen to cover the study area. Hurricane track, pressure deficit, RMW of Ivan for the 36 hours before landfall were input to the 2-D storm Surge Model. The Model was run and the total storm tide calculated for the

same locations as the HWM data listed in Table 1. Figure 10 and Table 2 display the result of model calculated total storm tide and a comparison with the surveyed HWM data.

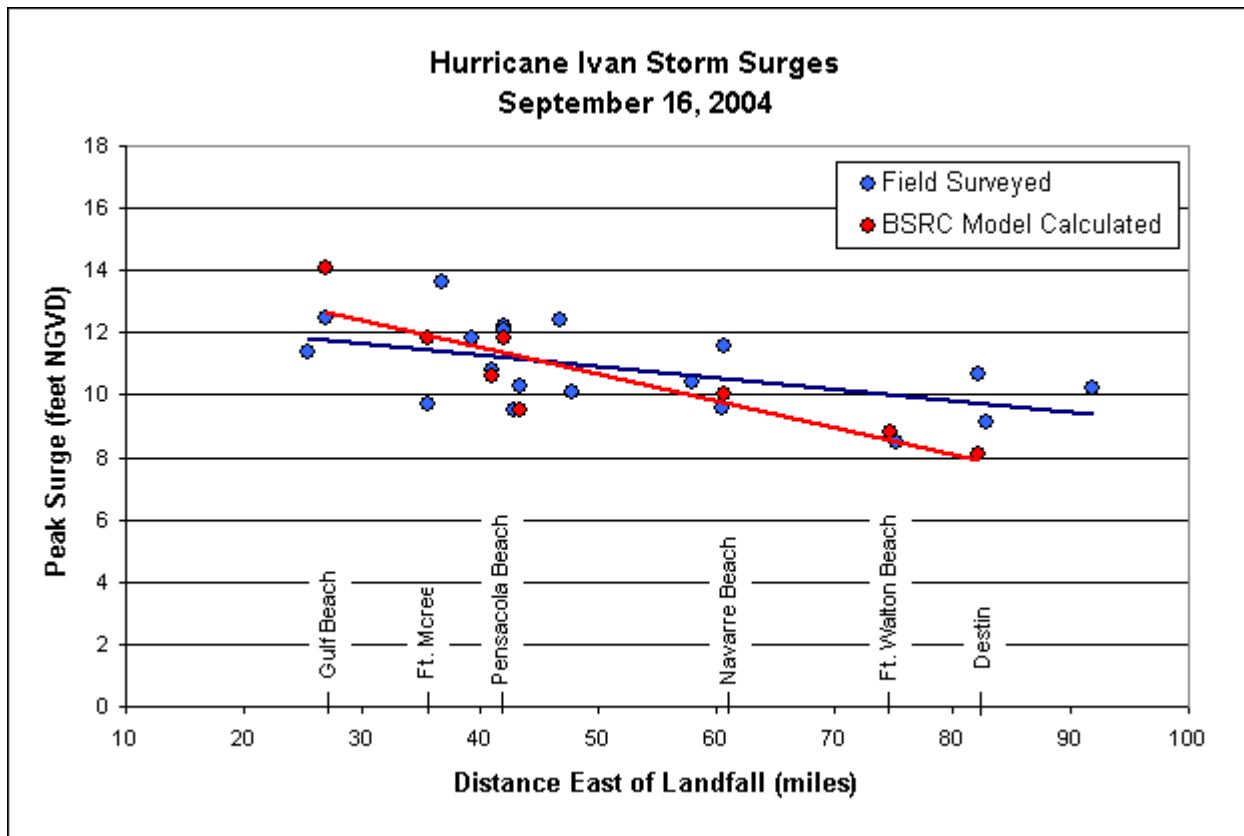


Figure 10. Comparison of Surveyed and BSRC Model Calculated Peak Surge Levels for Hurricane Ivan.

IV. Storm Tide Return Period

Figure 10 and Table 2 show that the BSRC Model calculated Total Storm Tide by Hurricane Ivan agrees closely with the Surveyed HWM data. The BSRC model results are validated herein, hence the CCCL study values can be used to show the storm tide return periods for the HWM data of Hurricane Ivan.

A total of 27 total storm tides in 9 profile transect lines from the CCCL studies for Escambia, Okaloosa and Walton Counties were selected to generate return periods of 50, 100 and 200 years. Figure 11 depicts a comparison between the surveyed HWM data and the CCCL's total storm tide for various return periods. Most HWM data are located within the 50 and 200 years return periods from Gulf Beach to Destin areas. By comparing the downward trend line of the HWM data to the return period range, Hurricane Ivan is estimated to have generated a 100 year storm tide for the Pensacola Beach area and a 50 year storm tide for the Destin area as shown in Figure 11.

Table 2 Comparison of BSRC Model Calculated Total Storm Tide with Surveyed HWM for Hurricane Ivan.

Location	BSRC Model Storm Tide Calculation (ft. NGVD)			Surveyed HWM (ft. NGVD)	
	Peak Surge	Astronomical Tide	Total Tide	FEMA HWM ¹	USCOE Gauge ¹
Gulf Beach-1	13.4	0.7	14.1	11.4	
Gulf Beach-2				12.5	
Ft. McRee-1	11.1	0.7	11.8		9.7
Ft. McRee-2				13.6	
Pensacola Bay-1	9.9	0.7	10.6	11.8	
Pensacola Bay-2				10.8	
Pensacola Beach-1	11.1	0.7	11.8	12.2	
Pensacola Beach-2				9.5	
Pensacola Beach-3				12.1	
Pensacola Beach-4				12.4	
Pensacola Beach-5				10.1	
Gulf Breeze	8.8	0.7	9.5		10.3
Navarre Beach-1	9.3	0.7	10.0	10.4	
Navarre Beach-2				9.6	
Navarre Beach-3				11.6	
Ft. Walton Beach-1	7.8	1.0	8.8	13.8	
Ft. Walton Beach-2				8.5	
Destin-1	7.1	1.0	8.1	10.7	
Destin-2				9.1	
Destin-3				13.4	
Destin-4				10.2	

¹ Interior HWM

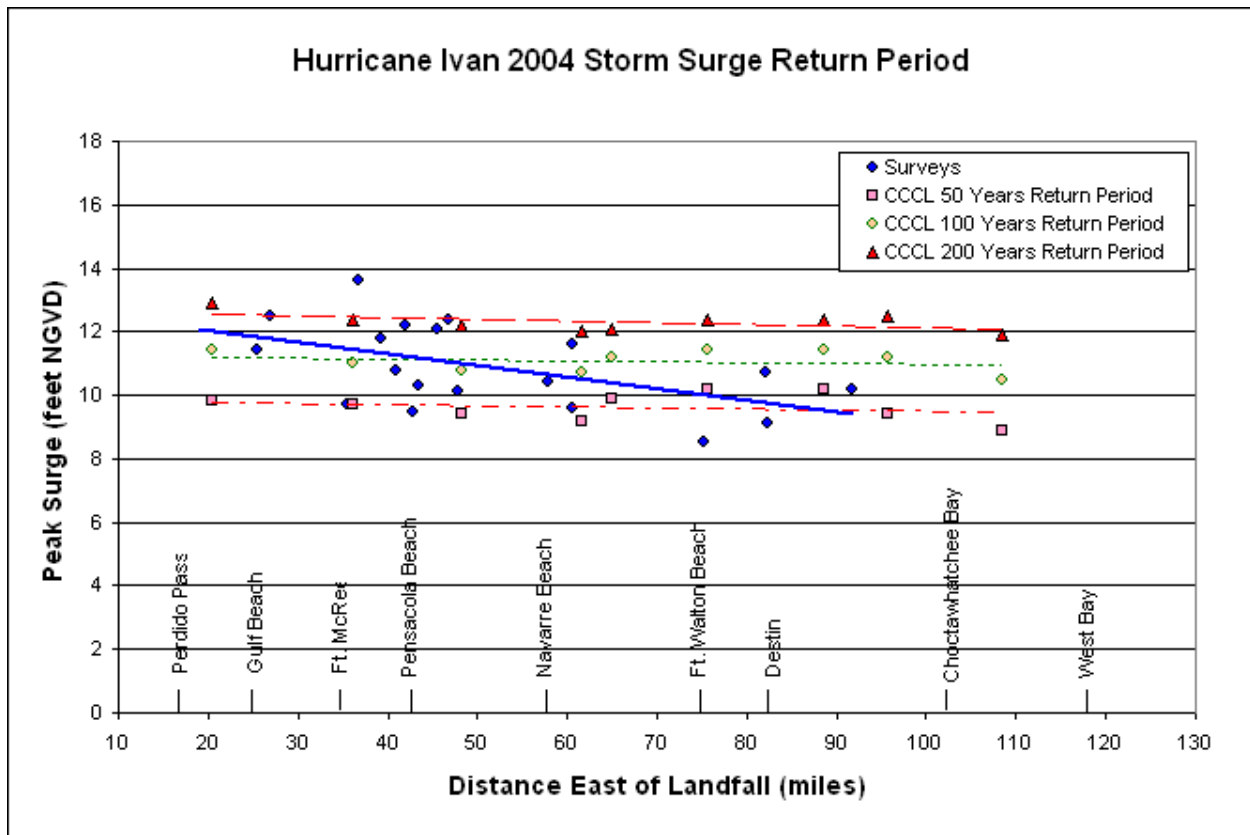


Figure 11. Hurricane Ivan Storm Tide Return Period.

V. Reference

Stewart, Stacy R., "Tropical Cyclone Report, Hurricane Ivan, 2-26 September 2004", Tropical Prediction Center, National Hurricane Center, January 2005.

FEMA, "Hurricane Ivan Rapid Response, Florida Coastal High Water Mark (CHWM) Collection, Task Order 336, Final Report", FEMA-1551-DR_FL, December 2004.