Tropical Cyclone Report
Hurricane Charley
9-14 August 2004

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Hurricane Charley strengthened rapidly just before striking the southwestern coast of Florida as a Category 4 hurricane on the Saffir-Simpson Hurricane Scale. Charley was the strongest hurricane to hit the United States since Andrew in 1992 and, although small in size, it caused catastrophic wind damage in Charlotte County, Florida. Serious damage occurred well inland over the Florida peninsula.

a. Synoptic History

A tropical wave emerged from western Africa on 4 August. Radiosonde data from Dakar showed that this wave was accompanied by an easterly jet streak of around 55 kt near the 650 mb level. The wave also produced surface pressure falls on the order of 5 mb over 24 h near the west coast of Africa. On satellite images this system was not particularly impressive just after crossing the coast, since it had only a small area of associated deep convection. As the wave progressed rapidly westward across the tropical Atlantic, the cloud pattern gradually became better organized, with cyclonic turning becoming more evident in the low clouds. The first center position estimates were given by the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB) in the vicinity of 9-10ºN, 47ºW at 2345 UTC 7 August, although at that time the system was still too weak to classify by the Dvorak technique. The first Dvorak T-numbers were assigned 24 h later, when the system was centered near 11ºN, 55ºW. Curved banding of the deep convection became better defined over the ensuing 12 h, and this, along with surface observations from the southern Windward Islands, indicated that a tropical depression had formed by 1200 UTC 9 August, centered about 100 n mi south-southeast of Barbados. Figure 1 depicts the "best track" of the tropical cyclone's path. The wind and pressure histories are shown in Figs. 2 and 3, respectively. Table 1 is a listing of the best track positions and intensities.

Late on 9 August, the depression moved into the southeastern Caribbean Sea. A strong deep-layer high pressure area to the north of the tropical cyclone induced a swift west-northwestward motion, at 20-24 kt. With low vertical shear and well-established upper-level outflow, the depression strengthened into Tropical Storm Charley early on 10 August. Fairly steady strengthening continued while the storm moved into the central Caribbean Sea, and when Charley approached Jamaica on 11 August, it became a hurricane. By this time, the forward speed had slowed to about 14 kt. Charley's core remained offshore of Jamaica; the center passed about 35 n mi southwest of the southwest coast of the island around 0000 UTC 12 August. The hurricane then turned northwestward, and headed for the Cayman Islands and western Cuba. It continued to strengthen, reaching Category 2 status around 1500 UTC 12 August, just after passing about 15 n mi northeast of Grand Cayman. As Charley neared the western periphery of a mid-tropospheric ridge, it turned toward the north-northwest, its center passing about 20 n mi east of the east coast of the Isle of Youth at 0000 UTC 13 August. The eye of the hurricane crossed the south coast of western Cuba very near Playa del Cajio around 0430 UTC 13 August. Charley strengthened just before it hit western Cuba. Cuban radar and microwave imagery suggests that the eye shrank in size, and surface observations from Cuba indicate that the maximum winds were about 105 kt as it crossed the island. By 0600 UTC, the eye was emerging

from the north coast of Cuba, about 12 n mi west of Havana. Based on aerial reconnaissance observations, Charley weakened slightly over the lower Straits of Florida. Turning northward, the hurricane passed over the Dry Tortugas around 1200 UTC 13 August with maximum winds near 95 kt.

By the time Charley reached the Dry Tortugas, it came under the influence of an unseasonably strong mid-tropospheric trough that had dug from the east-central United States into the eastern Gulf of Mexico. In response to the steering flow on the southeast side of this trough, the hurricane turned north-northeastward and accelerated toward the southwest coast of Florida. It also began to intensify rapidly at this time. By 1400 UTC 13 August, the maximum winds had increased to near 110 kt. Just three hours later, Charley's maximum winds had increased to Category 4 strength of 125 kt. Since the eye shrank considerably in the 12 h before landfall in Florida, these extreme winds were confined to a very small area – within only about 6 n mi of the center. Moving north-northeastward at around 18 kt, Charley made landfall on the southwest coast of Florida near Cayo Costa, just north of Captiva, around 1945 UTC 13 August with maximum sustained winds near 130 kt. Charley's eye passed over Punta Gorda at about 2045 UTC, and the eyewall struck that city and neighboring Port Charlotte with devastating results. Continuing north-northeastward at a slightly faster forward speed, the hurricane traversed the central Florida peninsula, resulting in a swath of destruction across the state. The center passed near Kissimmee and Orlando around 0130 UTC 14 August, by which time the interaction with land caused the maximum sustained winds to decrease to around 75 kt. Charley was still of hurricane intensity, with maximum sustained winds of 65-70 kt, when the center moved off the northeast coast of Florida near Daytona Beach at around 0330 UTC 14 August.

After moving into the Atlantic, the hurricane re-strengthened slightly as it accelerated north-northeastward toward the coast of South Carolina. This re-intensification proved to be temporary, however. Charley came ashore again near Cape Romain, South Carolina at about 1400 UTC 14 August as a weakening hurricane with highest winds of about 70 kt. The center then moved just offshore before making another landfall at North Myrtle Beach, South Carolina at around 1600 UTC 14 August, with intensity near 65 kt. Charley soon weakened to a tropical storm over southeastern North Carolina, and began to interact with a frontal zone associated with the same strong trough which had recurved it over Florida. By 0000 UTC 15 August, as the center was moving back into the Atlantic in the vicinity of Virginia Beach, Virginia, synoptic data indicate that the cyclone had become embedded in the frontal zone and was, therefore, an extratropical system. Charley's extratropical remnant moved rapidly north-northeastward to northeastward, and became indistinct within the frontal zone near southeastern Massachusetts just after 1200 UTC 15 August.

b. Meteorological Statistics

Observations in Charley (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the U. S. Air Force Weather Agency (AFWA), as well as flight-level and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command (AFRES). Microwave satellite imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA QuikSCAT, and Defense Meteorological Satellite Program (DMSP) satellites were also helpful in monitoring Charley. Finally, National Weather Service doppler radars were extremely useful for tracking this tropical cyclone. Figure 4 is a radar image of Charley around the time of landfall on 13 August from the Tampa radar, and shows the very small, well-defined eye of the hurricane.

Ship reports of winds of tropical storm force associated with Charley are given in Table 2, and selected surface observations from land stations and data buoys are given in Tables 3, 4, and 5. Charley destroyed instruments at the C-MAN observing site at Dry Tortugas.

Charley deepened extremely rapidly as it approached the southwest coast of Florida. Based on dropsonde measurements on 13 August from the AFRES, the central pressure fell from 964 mb at 1522 UTC to 941 mb at 1957 UTC, around the time of landfall, a deepening rate of about 5.02 mb h^{-1}. The hurricane's peak intensity is estimated to be 130 kt, which occurred at landfall in Cayo Costa, FL. This estimate is based on maximum 700 mb flight-level winds of 148 kt measured in the southeastern quadrant of the hurricane's eyewall at 1955 UTC 13 August. As usual, there were no official surface anemometer measurements of wind speeds even approaching the intensity estimate near the landfall location. The wind sensor at the Punta Gorda ASOS site, which experienced the eyewall of Charley, stopped reporting after measuring a sustained wind of 78 kt at 2034 UTC with a gust to 97 kt at 2036 UTC. Ten minutes later, that site reported its lowest pressure, 964.5 mb. Since it is presumed that the center was closest to the Punta Gorda site at the time of lowest pressure, and since Charley's maximum winds covered an extremely small area, it is highly likely that much stronger winds would have been observed at the site, had the wind instrument not failed. Instrument failures remain a chronic problem in landfalling hurricanes. Based on the few wind sensors that did *not* fail, Charley carried strong winds well inland along its path across the Florida peninsula. For example, Orlando International Airport measured sustained winds of hurricane force (69 kt), with a gust to 91 kt.

Observations from Cuba (Table 3) indicate that Charley was of category 3 intensity as it crossed the island. Radar and microwave imagery suggest that the hurricane was strengthening as it approached the south coast of Cuba. Storm surge heights of 13.1 ft were determined from high water marks at Playa Cajio on the south coast.

Rainfall totals of up to about 5 inches were reported in western Cuba. Maximum rainfall totals from gauges in Florida ranged up to a little over 5 inches, but radar-estimated storm total precipitation over central Florida were as high as 6 to 8 inches. Rainfall totals of 5 to 7 inches, locally a little higher, were observed over portions of eastern South Carolina and eastern North Carolina.

There were nine tornadoes reported across the Florida peninsula in association with Charley, all of which occurred on 13 August. There was 1 tornado in Lee County (a waterspout that moved onshore), 1 in Hendry County, 1 in DeSoto County, 1 in Hardee County, 2 in Polk County, 1 in Osceola County, and 2 in Volusia County. The strongest tornado was in south Daytona Beach. This tornado struck around 2326 UTC, and produced a quarter mile long track of F1 damage. There were five tornadoes reported in eastern North Carolina on 14 August, in Onslow, Pitt, (mainland) Hyde, Tyrrell, and (Outer Banks) Dare Counties. The tornado in Dare County produced F1 damage in Kitty Hawk. There were also two tornadoes observed in Virginia, in Chesapeake and Virginia Beach.

A storm surge of 4.2 feet was measured by a tide gauge in Estero Bay, near Horseshoe Key. This is near Fort Myers Beach. Storm surges of 3.4 and 3.6 feet were measured on tide gauges on the Caloosahatchee River, near Fort Myers. There were also visual estimates of storm surges of 6 to 7 feet on Sanibel and Estero Islands.

c. Casualty and Damage Statistics

Charley was directly responsible for 10 deaths in the United States. In Charlotte County, Florida a husband and wife, who were in a mobile home destroyed by the hurricane, were killed,

and two men died after being struck by flying debris. In Lee County, Florida, a man died as a result of a tree falling onto the structure he was in. In Sarasota County, Florida, the severe weather associated with Charley caused a woman to drive off the road and hit a tree, resulting in her death. In DeSoto County, Florida, a man was killed while in a tool shed hit by strong winds. In Orange County, Florida, a girl died as a result of strong winds blowing a moving van into the vehicle she was in, and in Polk County, Florida, a man drowned when he drove off of a flooded highway into a lake. In Rhode Island, a man drowned in a rip current. There were also 4 deaths in Cuba and 1 in Jamaica. Therefore, the direct death toll due to Charley stands at 15. An additional 25 U.S. deaths, 24 in Florida and 1 in South Carolina, were indirectly caused by Charley.

There are two estimates of insured damages in the United States from Hurricane Charley. The Property Claims Service reports insured damages of 6.755 billion dollars in Florida, 25 million dollars in North Carolina and 20 million dollars in South Carolina, making a total of 6.8 billion dollars in insured losses. The Insurance Information Institute reports an estimated total of 7.4 billion dollars in insured losses. Using a two to one ratio of total damages to these two insured damage amounts, a rough preliminary estimate of the total damage is 14 billion dollars. This would make Charley the second costliest hurricane in U.S. history. *Note: as of September 2011 the total damage estimate was revised to 15.113 billion dollars, which currently makes Charley was the sixth costliest hurricane in U.S. history (behind Katrina 2005, Ike 2008, Andrew 1992, Wilma 2005, and Ivan 2004).*

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Charley were 37 (20), 71 (18), 89 (16), 83 (14), 176 (10), 459 (6), and 777 (2) n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. In comparison, the longer-term average official track errors for the 10-yr period 1994-2003[1] are 44, 78, 112, 146, 217, 248, and 319 n mi. So the mean official track forecasts for Charley were better than the 10-yr average through 72 h, and significantly worse at 96 h and 120 h. It should be noted that there were very few forecasts to verify for the latter two forecast times, however. Table 6 lists the average errors from various numerical track prediction techniques for Charley. The GFS and FSU Superensemble generally performed best at hours 12-48, and the GFDL was best overall at 72-120 h – albeit for a small number of cases. Average official intensity errors were 7, 9, 14, 19, 25, 23 and 8 kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. For comparison, the average official intensity errors over the 10-yr period 1994-2003 are 6, 10, 12, 15, 19, 20, and 21 kt, respectively.

For about 24 h prior to hitting the United States, the official intensity forecasts called for Charley to strengthen from a category 2 to a category 3 hurricane by landfall on the west coast of Florida. A special advisory package was issued around 1800 UTC 13 August to report that Charley had strengthened into a category 4 hurricane. In this special advisory, a revised, eastward-shifted, track forecast was also issued, to account for a modest (by historical measures) deviation from the forecast track.

Although the official track forecasts for the landfall of Charley on the Florida west coast did, in general, have a left bias, the hurricane made landfall within the area covered by the hurricane watch and warning. One day prior to the Florida landfall, the 24-h track forecast error was 40 n mi, which is below the long-term average. Table 7 lists all of the watches and warnings issued for Charley. It can be seen that a hurricane watch was issued for the southwest coast of

[1] Errors given for the 96 and 120 h periods are averages over the three-year period 2001-3.

Florida, including the landfall location, just less than 35 h prior to landfall on that coast. A hurricane warning was issued for the same area just less than 23 h prior to landfall. No one near the landfall location should have been surprised by the arrival of this hurricane.

Table 1. Best track for Hurricane Charley, 9-14 August 2004.

Date/Time (UTC)	Latitude (EN)	Longitude (EW)	Pressure (mb)	Wind Speed (kt)	Stage
09 / 1200	11.4	59.2	1010	30	tropical depression
09 / 1800	11.7	61.1	1009	30	"
10 / 0000	12.2	63.2	1009	30	"
10 / 0600	12.9	65.3	1007	35	tropical storm
10 / 1200	13.8	67.6	1004	40	"
10 / 1800	14.9	69.8	1000	45	"
11 / 0000	15.6	71.8	999	55	"
11 / 0600	16.0	73.7	999	55	"
11 / 1200	16.3	75.4	995	60	"
11 / 1800	16.7	76.8	993	65	hurricane
12 / 0000	17.4	78.1	992	65	"
12 / 0600	18.2	79.3	988	75	"
12 / 1200	19.2	80.7	984	80	"
12 / 1800	20.5	81.6	980	90	"
13 / 0000	21.7	82.2	976	90	"
13 / 0600	23.0	82.6	966	105	"
13 / 1200	24.4	82.9	969	95	"
13 / 1400	24.9	82.8	965	110	"
13 / 1700	25.7	82.5	954	125	"
13 / 1800	26.1	82.4	947	125	"
14 / 0000	28.1	81.6	970	75	"
14 / 0600	30.1	80.8	993	75	"
14 / 1200	32.3	79.7	988	65	"
14 / 1800	34.5	78.1	1000	60	tropical storm
15 / 0000	36.9	75.9	1012	40	extratropical
15 / 0600	39.3	73.8	1014	35	"
15 / 1200	41.2	71.1	1018	30	"
15 / 1800					merged with front
13 / 0430	22.7	82.6	966	105	landfall on south coast of Cuba near Playa del Cajio
13 / 1945	26.6	82.2	941	130	landfall near Cayo Costa, FL, and minimum pressure
13 /2045	26.9	82.1	942	125	Landfall near Punta Gorda, FL
14 / 1400	33.0	79.4	992	70	landfall near Cape Romain, SC
14 / 1600	33.8	78.7	997	65	landfall near North Myrtle Beach, SC

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Charley, 9-14 August 2004.

Date/Time (UTC)	Ship call sign	Latitude (ºN)	Longitude (ºW)	Wind dir/speed (kt)	Pressure (mb)
10 / 0600	3FPS9	19.4	66.6	130 / 98	1018.0
10 / 2100	WCZ523	16.1	70.2	110 / 47	1010.0
11 / 0100	41545	22.1	71.1	missing / 39	1018.7
13 / 0900	C6YC	23.4	82.0	160 / 55	1008.0
13 / 1200	C6YC	23.2	82.9	230 / 52	1009.0
14 / 0600	WDA406	29.1	77.4	130 / 35	1018.0
14 / 1200	WDA406	28.9	78.6	150 / 35	1017.1
14 / 1500	WGMJ	31.7	77.6	180 / 38	1018.3
15 / 0300	A8BZ6	37.0	74.6	220 / 42	1017.0

Table 3. Selected surface observations for Hurricane Charley, 9-14 August 2004.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Grand Cayman Islands								
Grand Cayman	12/1300	1008.2	12/1142	21	34			0.90
Cayman Brac	12/0800	1008	12/1615	35	49			0.12
Cuba								
Punta del Este	13/0000	1001.7	13/0100	36	45			4.95
Nueva Gerona	13/0200	1006.2	13/0045	39	49			1.95
San Antonio de los Banos	13/0453	989.4	13/0453	97	115			
Guira de Melena	13/0459	971.6	13/0450	92	116			3.88
Bauta	13/0530	971.0						3.34
Playa Baracoa	13/0605	974	13/0530	103	130			
Santiago de las Vegas	13/0501	990.7	13/0620	63	79			4.19
Casa Blanca	13/0530	1001.7	13/0630	61	76			2.22
Playa Cajio						13.1		
Florida								
Key West (KEYW)	13/1153	1009.8	13/1413	42	50			1.44
Key West Naval Air Station (KNQX)	13/1155	1010.2	13/1255	34	45			1.23
Marathon (KMTH)	13/0953	1012.4	13/1506		34			0.53
Summerland Key (NWS Handar)			13/1250	29	45			0.30
Big Pine Key (NWS Handar)			13/1350	31	39			0.37
Naples (*) (KAPF)	13/1905	1004.4	13/1806	38	48			1.75
Everglades City (KEGC)			13/1801	40	55			
Flamingo (KFLM)			13/1606	38	47			
Miami (KMIA)	13/1941	1013	13/1710	26	34			0.47
Fort Lauderdale (KFLL)	13/1929	1010	13/1900	25	33			0.41
West Palm Beach (KPBI)	13/2045	1013	13/2000	26	33			0.40
Brighton Reservation CO-OP								1.92
Clewiston CO-OP								1.65
Devils Garden CO-OP								1.75

Marco Island CO-OP								1.04
Golden Gate CO-OP								2.08
Punta Gorda (KPGD)*	13/2046	964.5	13/2034	78	97			
Fort Myers (KFMY)	13/1953	998.1	13/2009	43	66			
Fort Myers (KRSW)	13/1957	1001.4	13/1949	53	68			
Sarasota (KSRQ)	13/2121	1003.4	13/0801	27	31			
St. Petersburg (KPIE)	13/2259	1008.5	13/2205	22	28			
St. Petersburg (KSPG)	13/2242	1007.1	13/0850	27	32			
Tampa (KTPA)	13/2332	1007.8	13/2257	20	26			
Winter Haven (KGIF)	13/2305	1000.3	13/2302	41	54			
Kissimmee (KISM)*			14/0035	53	65			5.20
Orlando (KMCO)*	14/0139	984.2	14/0134	69	91			2.11
Orlando (KORL)*	14/0129	980.7	14/0129	57	74			2.37
Sanford (KSFB)*	14/0213	983.4	14/0210	63	80			3.49
Lessburg (KLEE)	14/0158	1005.1	14/0135	29	34			
Patrick AFB (KCOF)			14/0044	28	43			
Daytona Beach (KDAB)*			14/0353	48	72			3.43
Ormond Beach (KOMN)			14/0315	59	76			
Melbourne (KMLB)	14/0100	1010.5	14/0222	29	39			1.44
Ft. Pierce (KFPR)			13/1910	21	26			
Stuart (KSUA)			13/1955	20	31			
Vero Beach (KVRB)			14/0136	23	30			
Gainesville (KGNV)	14/0442	1011.6	14/1952	10	13			0.04
Jacksonville (KJAX)	14/0612	1009.9	14/0358	17	20			
Craig Field (Jacksonville) (KCRG)	14/0521	1008.2	14/0501	21	29			
NAS Jacksonville (KNIP)	14/0456	1012.4	14/0433	30	34			
NAS Mayport (KNRB)*	14/0529	1007.2	14/0430	37	46			
Fernandina Beach NOS	14/0700	1008.5	14/0742	18	28	0.89	2.68	0.67*
Mayport NOS	14/0700	1008.3	14/0500	30	42	1.61	2.19	
Vilano Beach NOS (29.9ºN 81.3ºW)			14/0500	27	44			
Bings Landing NOS (29.6ºN 81.2ºW)	14/0500	1000.6	14/0500	18	57			
Cresent Beach NOS (29.8ºN 81.3ºW)			14/0500	26	58			
Georgia								
St. Simons Island (KSSI)	14/0723	1009.5	14/0654	18	22	0.68	3.82	
Alma (KAMG)	14/0747	1012.9	14/2103	8	11			0.01

Baxley CO-OP								0.51
Savannah (KSAV)	14/1024	1012	14/1143	13	17			0.53
South Carolina								
Charleston (KCHS)	14/1258	1008	14/1322	25	33			1.02
North Myrtle Beach (KCRE)	14/1609	998	14/1538	36	50			1.52
Myrtle Beach (KMYR)			14/1550	35	45			
Florence (KFLO)	14/1552	1014	14/1742	20	25			0.03
North Carolina								
Wilmington (KILM)	14/1750	1005	14/1731	48	64			2.02
Southport (KSUT)			14/1700	33	51			2.26
Elizabethtown CO-OP								3.32
Burgaw CO-OP								3.32
Whiteville CO-OP								3.22
New River (KNCA)	14/1815	1008.1	14/1929	42	57			
New Bern (KEWN)	14/1900	1012.1	14/1847	34	46			1.26
Cherry Point (KNKT)	14/1855	1014.1	14/1857	31	44			2.08
Beaufort (KMRH)	14/1756	1017.1	14/1915	32	43			1.40
Cape Hatteras (KHSE)	14/2051	1017.4	14/2154	26	32			0.01
Manteo (KMQI)	14/2120	1015.1	14/2200		35			
Washington (KOCW)	14/1900	1012.4	14/2001		50			
Edenton (KEDE)			14/2140	38	56			
Jacksonville (KOAJ)	14/1835	1012.4	14/1835		48			1.73
Kinston (KISO)	14/1920	1009	14/1920		40			
Greenville (KPGV)	14/1901	1010.4	14/1921		32			
Elizabeth City (KECG)	14/2106	1011	14/2249	38	56			2.30
Greenville CO-OP								5.05
Kinston CO-OP								4.38
Richlands CO-OP								3.41
Williamston CO-OP								2.50
Ocracoke CO-OP								0.04
Virginia								
Norfolk (KORF)	14/2305	1013	14/2208	31	39			3.72
Norfolk NAS (KNGU)	14/2356	1013	14/2314	27	38			2.66
Newport News (KPHF)			14/2218	16	27			2.34
Hampton- Langley AFB (KLFI)			14/2214	e30	e42			
Wallops Island	14/2354	1017	14/2354	18	23			3.17

Washington National (KDCA)	15/0051	1020.1		13	16			0.60
Maryland								
Ocean City (KOXB)			15/0053	17	25			1.86
Patuxent NAS (KNHK)	14/2355	1018.2	14/2355	15				
Baltimore (KBWI)	15/0054	1020.0	15/0054	7	16			0.29

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).
* Instrument failed.

Table 4. Selected Buoy and C-MAN observations for Hurricane Charley, 9-14 August 2004.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
C-MAN								
Sand Key (SANF1)	13/1159	1007.8	13/1159	44	54			
Sombrero Key (SMKF1)	13/1059	1012.4	13/1449	41	56	1.83		
Long Key (LONF1)	13/1159	1012.0	13/1329	38	53	1.81		
Molasses Reef (MLRF1)	13/0853	1012.9	13/0359	34	47			
Dry Tortugas (DRYF1)*	13/1059	1004.7	13/1059	36	46			
Northwest Florida Bay (NFBF1) (USF)	13/1200	1011.6	13/1554	31	39	2.13		
Egmont Key (EGKF1)			13/2100	23	27			
Anna Maria (ANMF1)	13/2000	1008.1	13/2230	27	29			
St. Augustine (SAUF1)	14/0505	1000.7	14/0450	51	63			
Folly Beach (FBIS1)	14/1300	1005	14/1200	41	50			
US Navy Tower (SPAG1) (31.4ºN 80.6ºW)	14/1305	990						
Duck (DUCN7)	14/2100	1016.1	14/2200	32	47			
Cape Lookout (CLKN7)	14/1900	1015.9	14/2000	30	46			
Frying Pan Shoals (FPSN7)	14/1600	1014.4	14/1700	33	43			
Chesapeake Light (CHLV2)	14/2200	1013	14/2251	43	63			
Buoys								
Buoy 41009- East of Cape Canaveral (28.5ºN 80.2ºW)	14/0150	1011.0	14/0150	35	44			
Buoy 41012- St. Augustine (30.0ºN 80.6ºW)	14/0650	999.0	14/0450	37	47			
Buoy 41004- Edisto (32.5ºN 79.1ºW)	14/1250	1001	14/1250	43	64			
Buoy 41008- Grays Reef (31.4ºN 80.9ºW)	14/0850	1005	14/0850	33	43			
Buoy 41013- Frying Pan Shoals (33.5ºN 77.6ºW)	14/1550	1014.4	14/1650	36	49			
Buoy 44009- Delaware Bay (38.5ºN 74.7ºW)			15/0350	25	31			

[a] Date/time is for sustained wind when both sustained and gust are listed.

[b] Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.

[c] Storm surge is water height above normal astronomical tide level.

[d] Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

* Instrument failed.

Table 5. Unofficial observations for Hurricane Charley, 9-14 August 2004.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Florida								
Key West Harbor	13/1200	1010.2	13/1612	32	44	1.44		
Cudjoe Key			13/1205		44			
Duck Key			13/0300	33	45			
Curry Hammock St. Park								1.04
Tavernier								0.70
Dry Tortugas/Fort Jefferson						e 6.0		
Lake Okeechobee			13/2000	35				
Vanderbilt Beach*			13/1950		73			
Naples			13/1930		47			
Moore Haven			13/2045		36			
Immokalee			13/2015		26			
North Naples								7.48
Arcadia EOC	13/2130	975.7	13/2140		90			
Charlotte County Airport			13/2035		139			
Charlotte County Medical Center			13/2035		150			
Port Charlotte			13/2000		61			
Storm Chaser Mark Sudduth, near Port Charlotte (27.0ºN 82.0ºW)	13/2057	943.6	13/2046	80	115			
Storm Chaser Jim Leonard in Port Charlotte, near Faucet Memorial Hospital	13/2051	950.0						
Storm Chaser Mike Theiss, near Charlotte Harbor	13/2042	942.0						
Storm Chaser Jim Edds in Punta Gorda	13/e2042	943.0						
Big Carlos Pass (Lee County) (26.4ºN 81.9ºW)	13/1954	997.1	13/1936	60	83			
Plant City			13/2355		54			
Fort Myers Beach			13/1930		56			
For Myers			13/2023		83			
Cape Coral			13/1940		78			

Matanzas Pass Fort Myers Beach						5.82		
Estero Bay Horseshoe Key						4.46		
Port Boca Grand						4.30		
Sarasota			13/2119		44			
Lakeland			13/2336		50			
Haines City			13/2325		67			
Lake Wales (10 mi East)			13/2300		65			
Poinciana			14/0000		39			
Archbold			13/2100		49			
NASA Wind Tower 421 (28.78ºN 80.8ºW)			14/0250	56	75			
NASA Wind Tower 22 (28.8ºN 80.8ºW)			14/0250	53	75			
Daytona Beach International Airport Wind Shear			14/0325		84			
4 miles southwest of Wimauma		1005.8	13/2200	35	48	2.22		
South Florida Water Management District (SFWMD) station WRWX Polk County (28.05ºN 81.40ºW)	14/0015	991.3	13/2116		57			
SFWMD S65DWX Highlands County (27.31ºN 81.02ºW)			13/2306		50			
SFWMD S61W (28.14ºN 81.35ºW)	14/0030	990.7	14/0028		78			
SFWMD S65CW (27.40ºN 81.11ºW)			13/2242		50			
SFWMD S65DWX (27.31ºN 81.02ºW)			13/2216		50			
SFWMD L001 (27.14ºN 80.79ºW)			13/2234		46			
South Carolina								
Downtown Charleston (wind- 10 min. avg.)			14/1238	32	44			2.09
Pineville (wind- 10 min. avg.)			14/1520	17	24			0.19
Isle of Palms			14/1230	43	55			2.00
Hampton								1.53
Ravenel								0.45
Walterboro								0.40
Summerville								0.24
Charleston Harbor						e 2.0		

Oyster Landing (N. Charleston County)						2.94		
Myrtle Beach Springmaid Pier (wind- 6 min. avg.)	14/1542	998.2	14/1506	39	53	e 6.0	7.19	
Little River FD					50			1.69
Myrtle Beach Pavilion					65			2.60
Loris					50			3.09
Conway								4.25
Conway Horry County EOC								3.97
Outland (Georgetown County)								2.97
North Carolina								
Wrightsville Beach Johnnie Mercer Pier (wind- 6 min. avg.)	14/1736	1007.3	14/1736	61	74			
Sunset Beach	14/1600	998	14/1500	46	53			
Surf City					44			
Watha					39			
Wilmington Battleship USS NC					61			1.39
UNC Wilmington Marine Science Center					72			2.14
Wrightsville Beach US Coast Guard Station					63			
North Carolina St Port					80			
Bay Shore Estates					81			
Carolina Beach					61			
Myrtle Grove					55			
Southport					74			
Oak Island (39th Place West)					66			
Oak Island (43rd St. East)					53			
St. James Plantation					58			
Holden Beach					74			
Cedar Island			14/2000		42			
Brunswick County						e 7-8		
Bald Head Island						e 2-3		
New Hanover County Onslow Bay						e 5.0		
Pender County						e 4.0		
Onslow County						e 2-3		

Carteret County Bogue Banks						e 2-3		
Whiteville Columbus County Airport								1.88
Lumberton								0.62
Longwood								1.80
Moores Creek								1.56
Newport								2.30
Havelock								2.28
Perrytown								1.23
Virginia								
Chesapeake BBT	15/0000	1013	14/2154	45	51			
Sewell's Point	14/2212	1015	14/2336	38	49			
Kiptopeke			14/2348	25	36			
Marlyand								
Ridge					16			2.07

[a] Date/time is for sustained wind when both sustained and gust are listed.

[b] Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.

[c] Storm surge is water height above normal astronomical tide level.

[d] Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

Table 6. Preliminary forecast evaluation (heterogeneous sample) for Hurricane Charley, 9-14 August 2004. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecasts are shown in bold-face type. Verification includes the depression stage.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	53 (20)	130 (18)	201 (16)	258 (14)	394 (10)	587 (6)	969 (2)
GFNI	52 (17)	97 (13)	156 (11)	227 (9)	227 (5)		
GFDI	40 (19)	75 (17)	101 (15)	124 (13)	**159** (9)	**396** (5)	797 (1)
GFDL	**36** (19)	**66** (17)	89 (15)	119 (13)	**128** (9)	**276** (5)	**629** (1)
GFDN	56 (17)	96 (14)	147 (12)	206 (10)	326 (5)		
LBAR	43 (20)	81 (18)	109 (16)	134 (14)	204 (10)	**381** (6)	**726** (2)
GFSI	**35** (18)	**63** (16)	91 (14)	117 (11)	**169** (7)	**430** (3)	
GFSO	**35** (19)	**54** (17)	**74** (14)	103 (12)	**167** (8)	**362** (4)	
AEMI	**33** (11)	80 (9)	111 (7)	144 (5)	**67** (3)		
AEMN	40 (12)	**59** (10)	91 (8)	140 (6)	**64** (2)	**73** (1)	
BAMD	50 (20)	102 (18)	163 (16)	239 (14)	358 (10)	552 (6)	956 (2)
BAMM	52 (20)	104 (18)	156 (16)	218 (14)	348 (10)	**440** (6)	**711** (2)
BAMS	60 (20)	111 (18)	154 (16)	189 (14)	308 (10)	**394** (6)	**649** (2)
NGPI	49 (18)	80 (16)	105 (14)	154 (12)	302 (8)	614 (4)	
NGPS	62 (18)	93 (16)	109 (14)	133 (12)	245 (8)	526 (5)	1151 (1)
UKMI	51 (16)	98 (14)	159 (12)	221 (10)	352 (7)	697 (2)	
UKM	64 (9)	94 (8)	136 (7)	204 (6)	338 (4)	495 (1)	
A98E	50 (20)	99 (18)	140 (16)	170 (14)	341 (10)	592 (6)	1064 (2)
A9UK	55 (10)	110 (9)	154 (8)	190 (7)	305 (5)		
GUNS	44 (16)	76 (14)	103 (12)	130 (10)	224 (7)	684 (2)	
GUNA	39 (16)	**67** (14)	90 (12)	109 (10)	187 (7)	641 (2)	
FSSE	**36** (16)	**59** (14)	**79** (12)	96 (10)	187 (7)	572 (3)	
CONU	42 (18)	71 (16)	97 (14)	119 (12)	**173** (8)	459 (4)	
OFCL	37 (20)	71 (18)	89 (16)	83 (14)	176 (10)	459 (6)	777 (2)
NHC Official, 1994-2003 mean (number of cases)	44 (3172)	78 (2894)	112 (2636)	146 (2368)	217 (1929)	248 (421)	319 (341)

Table 7. Watch and warning summary for Hurricane Charley, 9-14 August 2004.

Date/Time (UTC)	Action	Location
10/1500	Tropical Storm Watch Issued	Jamaica
10/2100	Tropical Storm Watch Issued	Cayman Islands
10/2100	Tropical Storm Watch changed to Tropical Storm Warning	Jamaica
10/2100	Tropical Storm Warning issued	Southwest Peninsula of Haiti from the Dominican Republic border westward including Port-au-Prince
11/0300	Hurricane Watch Issued	Jamaica
11/0300	Tropical Storm Watch changed to Tropical Storm Warning and Hurricane Watch	Cayman Islands
11/0900	Hurricane Watch Issued	Florida Keys from the Dry Tortugas to Craig Key
11/0900	Tropical Storm Warning and Hurricane Watch changed to Hurricane Warning	Cayman Islands
11/1500	Tropical Storm Warning Discontinued	Southwest Peninsula of Haiti from the Dominican Republic border westward including Port-au-Prince
11/1500	Hurricane Watch Issued	Cuban provinces of Pinar Del Rio, La Habana, Ciudad de la Habana, Matanzas, and the Isle of Youth
11/2100	Tropical Storm Warning and Hurricane Watch changed to Hurricane Warning	Jamaica
11/2100	Hurricane Watch Issued	East of Craig Key to Ocean Reef including Florida Bay and SW Florida from Flamingo to Bonita Beach
12/0300	Hurricane Watch Issued	North of Bonita Beach Florida to Anna Maria Island
12/0900	Hurricane Watch changed to Hurricane Warning	Florida Keys from the Dry Tortugas to the Seven Mile Bridge and SW Florida from E Cape Sable to Bonita Beach
12/0900	Tropical Storm Warning Issued	Florida Keys from Seven Mile Bridge to Ocean Reef including Florida Bay nd on the mainland west of Ocean Reef to E Cape Sable
12/0900	Hurricane Watch Issued	N of Bonita Beach to Tarpon Springs
12/1500	Hurricane Watch Issued	N of Tarpon Springs to Suwannee River Florida
12/1500	Hurricane Watch changed to Hurricane Warning	Cuban provinces of Pinar Del Rio, La Habana, Ciudad de la Habana, Matanzas, and the Isle of Youth
12/1500	Hurricane Warning Discontinued	Jamaica
12/2100	Hurricane Watch changed to Hurricane Warning	N of Bonita Beach FL to Bayport

12/2100	Tropical Storm Watch Issued	Jupiter Inlet FL north to Altamaha Sound Georgia including Lake Okeechobee
12/2100	Hurricane Warning Discontinued	Cayman Islands
13/0300	Hurricane Watch changed to Hurricane Warning	N of Bayport to the Suwannee River
13/0300	Tropical Storm Watch changed to Tropical Storm Warning	Lake Okeechobee
13/0300	Tropical Storm Watch Issued	S of Jupiter Inlet FL to Ocean Reef and N of Altamaha Sound to South Santee River South Carolina
13/0900	Hurricane Warning Issued	N of the Suwanne River to the Steinhatchee River FL
13/0900	Tropical Storm Watch changed to Tropical Storm Warning	Cocoa Beach FL to Altamaha Sound Georgia
13/0900	Tropical Storm Watch Issued	N of South Santee River SC to Cape Fear North Carolina
13/1100	Hurricane Warning Discontinued	Cuban provinces of Pinar Del Rio, La Habana, Ciudad de la Habana, Matanzas, and the Isle of Youth
13/1500	Tropical Storm Watch Issued	North of Cape Fear NC to Oregon Inlet NC including Pamlico Sound
13/1500	Hurricane Watch Issued	Flagler Beach FL northward to the Savannah River near the GA/SC border
13/1500	Tropical Storm Watch changed to Tropical Storm Warning	S of Cocoa Beach FL to Jupiter Inlet FL
13/1800	Tropical Storm Warning changed to Hurricane Warning	Cocoa Beach FL to Altamaha Sound GA
13/1800	Tropical Storm Watch changed to Hurricane Warning	N of Altamaha Sound GA to South Santee River SC
13/1800	Tropical Storm Watch changed to Tropical Storm Warning and Hurricane Watch	N of South Santee River SC to Cape Lookout North Carolina
13/2100	Watches/Warnings Discontinued	S of Jupiter Inlet along the Florida E coast to Ocean Reef and for all of the FL Keys
13/2100	Tropical Storm Warning and Hurricane Watch changed to Hurricane Warning	N of South Santee River SC to Cape Lookout North Carolina
13/2100	Tropical Storm Watch Issued	N of Oregon Inlet NC to Chincoteague Virgina including Albemarle Sound and for Lower Chesapeake Bay South of Smith Point
14/0100	Watches/Warnings Discontinued	All of the Florida West Coast
14/0300	Tropical Storm Warning Discontinued	Lake Okeechobee, FL
14/0300	Tropical Storm Watch changed to Hurricane Warning	N of Cape Lookout NC to Oregon Inlet including Pamlico and Albemarle Sounds

14/0300	Tropical Storm Watch changed to Tropical Storm Warning	N of Oregon Inlet NC to Chincoteague VA including Lower Chesapeake Bay South of Smith Point
14/0600	Tropical Storm Warning Discontinued	S of Cocoa Beach FL to Jupiter Inlet FL
14/0900	Tropical Storm Watch changed to Hurricane Warning	N of Oregon Inlet NC to the N Carolina/Virginia state border
14/0900	Tropical Storm Warning Issued	N of Chincoteague Virginia to Sandy Hook New Jersey including Upper Chesapeake Bay, the Tidal Potomac and Delaware Bay
14/0900	Tropical Storm Watch Issued	N of Sandy Hook NJ to the Merrimack River Massachusetts including New York Harbor and Long Island Sound
14/0900	Hurricane Warning Discontinued	Altamaha Sound GA south to Cocoa Beach FL
14/1500	Hurricane Warning Discontinued	South of the South Santee River SC to Altamaha Sound GA
14/1500	Tropical Storm Watch changed to Tropical Storm Warning	N of Sandy Hook NJ to the Merrimack River MA including New York Harbor and Long Island Sound
14/1800	Hurricane Warning changed to Tropical Storm Warning	Little River Inlet South Carolina to the NC/VA border
14/1800	Hurricane Warning Discontinued	S of Little River Inlet SC to South Santee River SC
14/2100	Tropical Storm Warning Discontinued	S of Cape Lookout NC to Little River Inlet SC
15/0000	Tropical Storm Warning Discontinued	S of Oregon Inlet NC to Cape Lookout NC including Pamlico Sound and for Chesapeake Bay N of Smith Point including the Tidal Potomac
15/0300	Tropical Storm Warning Discontinued	W of New Haven Connecticut to Oregon Inlet NC and Long Island W of Fire Island
15/1230	Tropical Storm Warning Discontinued	W of Watch Hill Rhode Island and for Long Island
15/1500	All Warnings Discontinued	

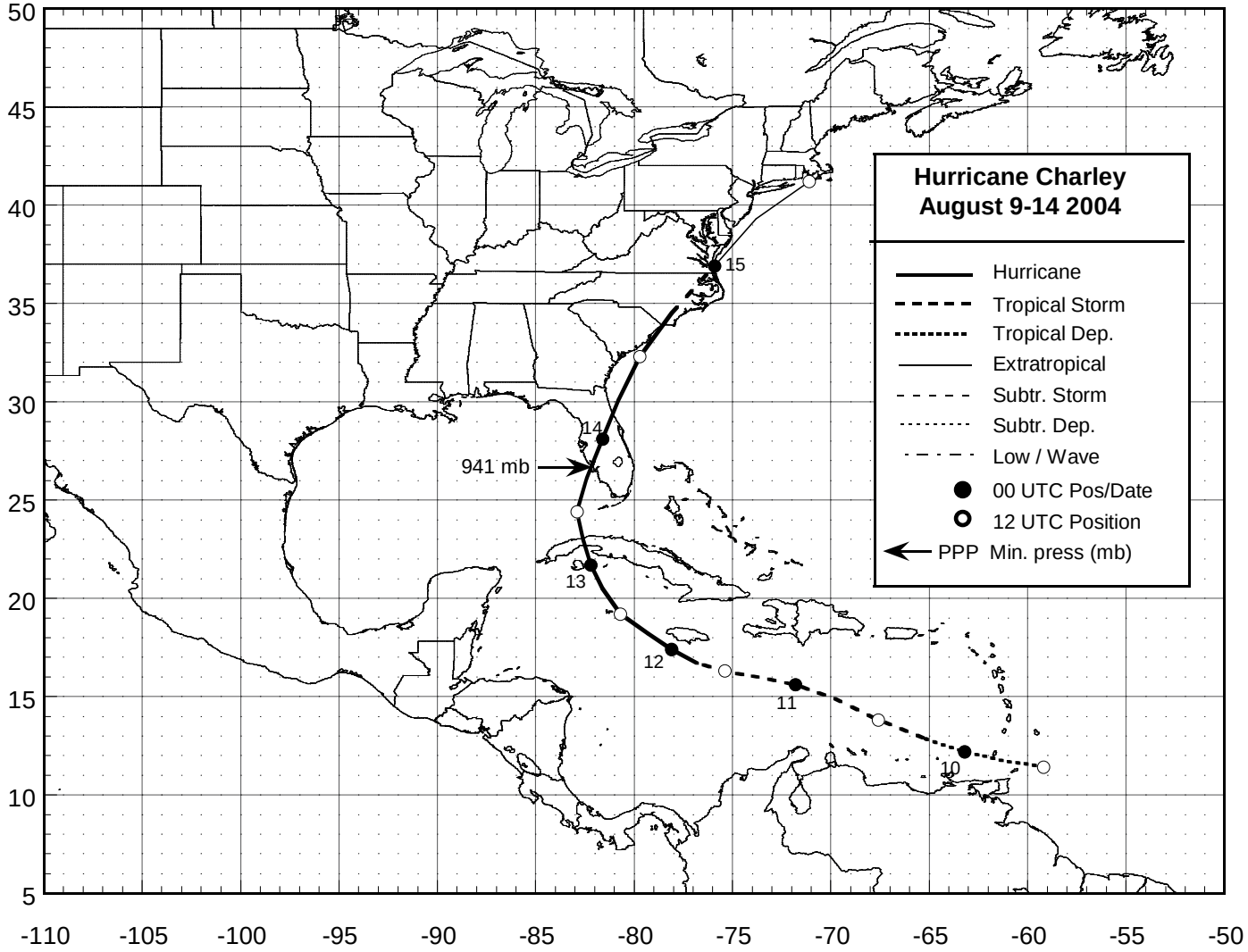

Figure 1. Best track positions for Hurricane Charley, 9-14 August 2004.

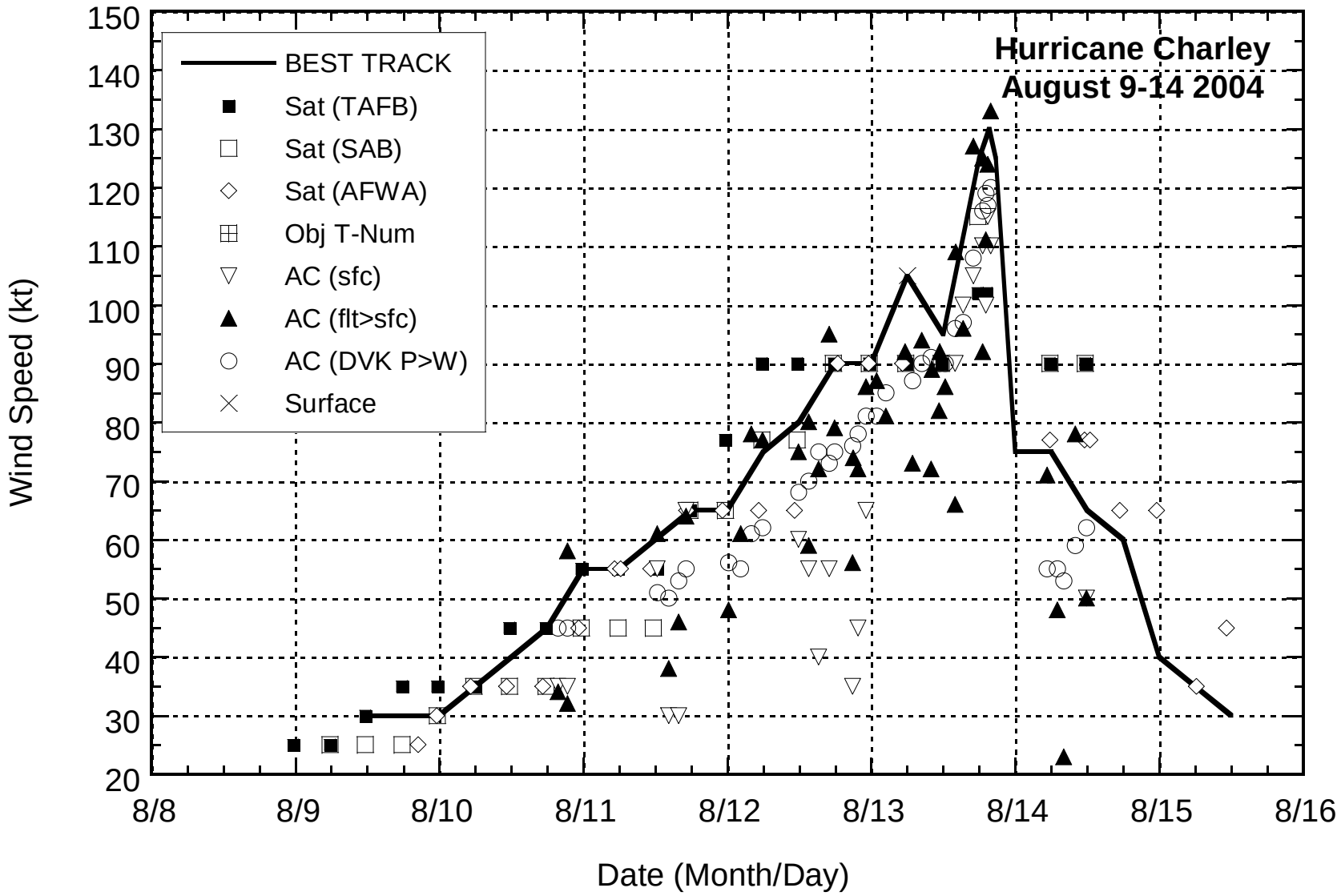

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Charley, 9-14 August 2004. Aircraft observations have been adjusted for elevation using 90% and 80% reduction factors for observations from 700 mb and 850 mb, respectively.

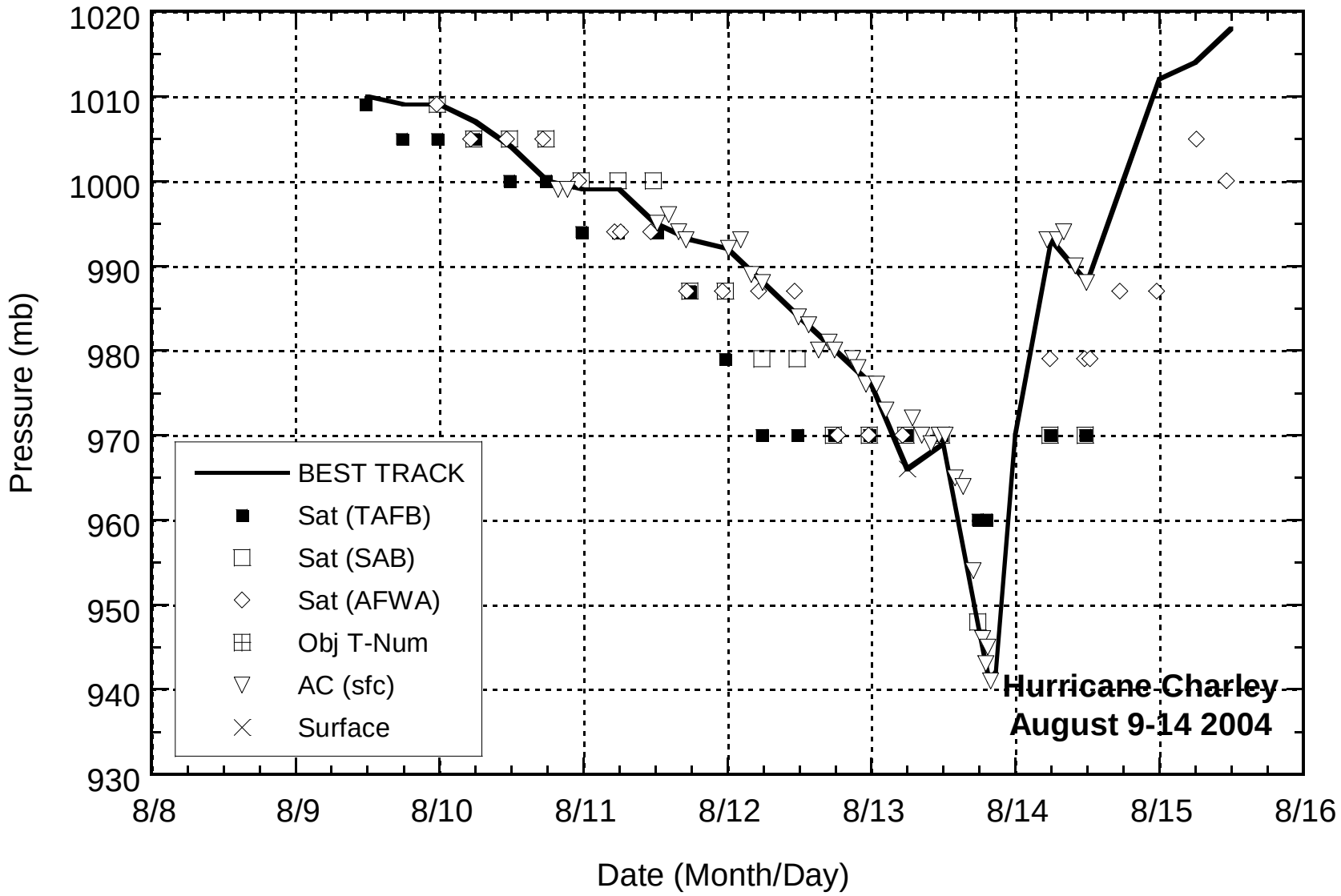

Figure 3. Pressure observations and minimum central pressure curve for Hurricane Charley, 9-14 August 2004.

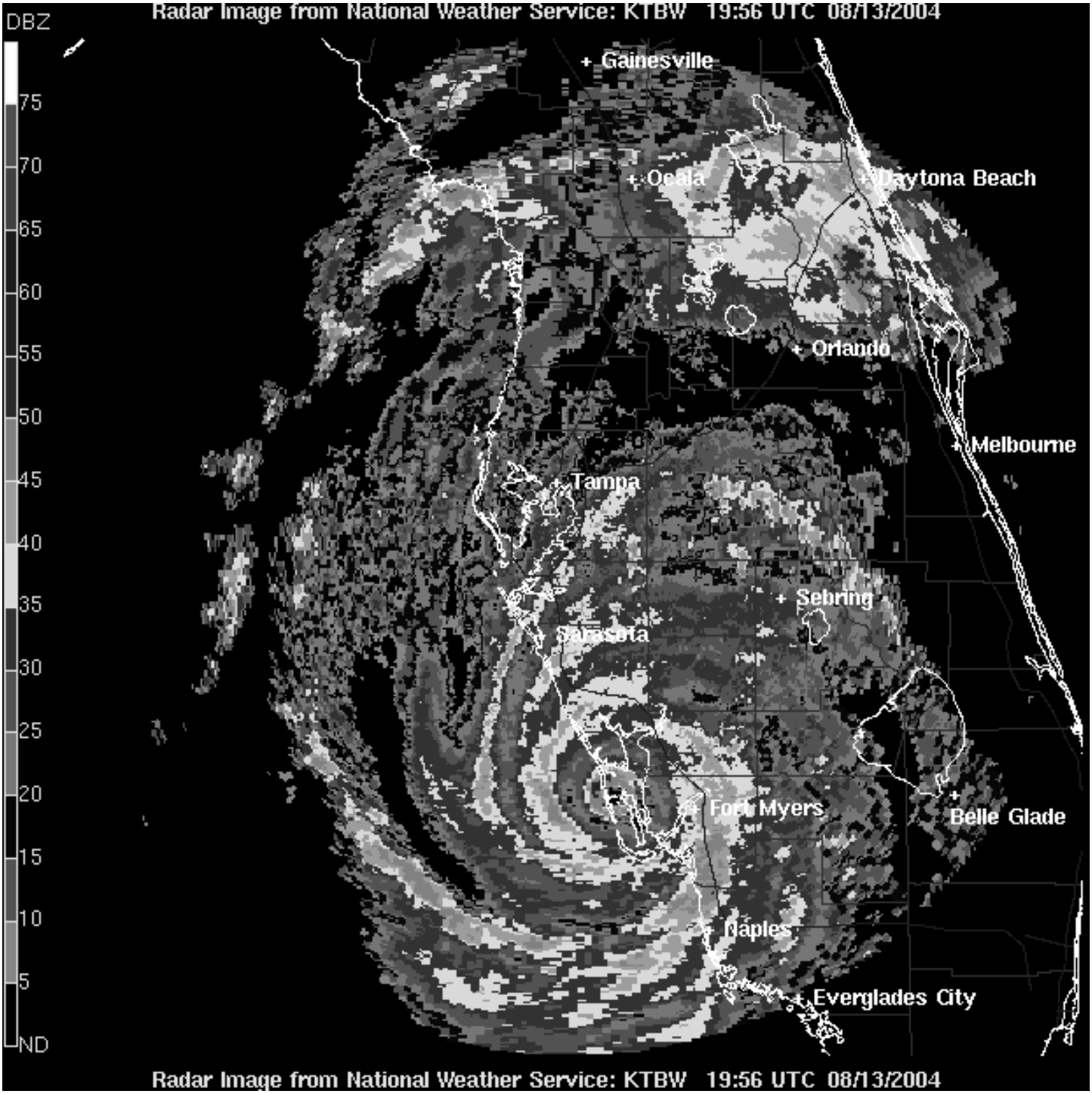

Figure 4. Radar image of Hurricane Charley from the Tampa Bay National Weather Service Forecast Office Doppler Radar at 2056 UTC 13 August 2004.