Tropical Cyclone Report
Hurricane Hanna
(AL082008)
28 August – 7 September 2008

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Hanna was a tropical cyclone that was briefly a hurricane over the Caicos Islands. Hanna also made landfall in the United States as a strong tropical storm near the border between North and South Carolina. Impacts from Hanna were greatest in Haiti, where heavy rainfall and subsequent flooding resulted in a large loss of life.

a. Synoptic History

Hanna formed from a tropical wave that entered the eastern Atlantic Ocean on 19 August. Associated shower and thunderstorm activity gradually increased as the wave progressed westward across the Atlantic, and on 26 August the wave spawned an area of low pressure about 475 n mi east-northeast of the northern Leeward Islands. Additional development continued during the next couple of days, which led to the formation of a tropical depression by 0000 UTC 28 August, about 275 n mi east-northeast of the northern Leeward Islands. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

It is estimated that the depression reached tropical storm strength 12 h later, as the overall organization of the system continued to improve. Visible satellite imagery later that day, however, indicated that the center of Hanna was located near the western edge of the deep convection due to westerly shear from an upper-level low to the northwest of the cyclone. Despite the moderate shear, the storm strengthened a little as it moved in a general west-northwestward direction to the south of a subtropical ridge extending over the western Atlantic. While passing a couple hundred miles to the north of Puerto Rico, Hanna moved close enough to the upper-level low that the satellite appearance of Hanna briefly resembled that of a sub-tropical storm on 30 August. The upper-level low shifted southward and gradually dissipated the next day, resulting in a low-shear environment conducive for strengthening. Deep convection began to form over the center of the storm around 0000 UTC 1 September. This continued overnight and into the next morning, when a period of rapid intensification (30 kt or more intensity increase in 24-h) began. During that time, a building deep-layer ridge over the eastern United States caused Hanna to turn southwestward and to slow its forward speed. Reconnaissance aircraft data indicate that Hanna reached hurricane strength by 1800 UTC 1 September, while centered just north of the Caicos Islands. Flight-level winds from the aircraft later that afternoon and a minimum surface pressure report of 978.9 mb (Table 3) from Pine Cay in the Caicos Islands suggest that Hanna reached an estimated peak intensity of 75 kt, while centered over

[1] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

Providenciales in the Caicos Islands around 0000 UTC 2 September. A passive microwave image around that time confirmed Hanna's rapid increase in organization, revealing the presence of a well-defined banded eye feature (Fig. 4). However, no sooner had Hanna strengthened than it abruptly began to weaken, succumbing to the effects of moderate to strong northerly shear associated with the building ridge over the United States, and Hanna weakened to a tropical storm by 1200 UTC 2 September.

During the time of Hanna's rapid weakening it moved on a general west-southwestward track, passing very near Great Inagua Island in the Southeastern Bahamas. Hanna turned southeastward later that day and passed less than 30 n mi from the north coast of Haiti early on 3 September. Later that day, Hanna interacted with another upper-level low over the Bahamas and once again exhibited a quasi-subtropical convective structure. The storm then turned northward and began to re-strengthen as it moved over Middle Caicos Island shortly after 1800 UTC 3 September. Hanna completed a counter-clockwise loop and began moving northwestward when a sub-tropical ridge built over the western Atlantic. During the next 24-36 hours, Hanna's intensity remained between 55 and 60 kt while the center passed just east of the central and northwestern Bahamas. By 5 September, Hanna separated from the upper-low and reached the western periphery of the subtropical ridge. The cyclone turned northward, its center passing about 150 n mi east of the coast of northern Florida. Hanna continued northward and accelerated, making landfall as a 60 kt tropical storm near the border between North and South Carolina at 0720 UTC 6 September. Once inland over North Carolina the storm began to weaken while moving across the Mid-Atlantic region. Hanna turned northeastward and its center passed very close to New York City shortly after 0000 UTC 7 September. Shortly thereafter, the system became extratropical when it merged with a cold front over southern New England.

The extratropical remnant of Hanna continued moving northeastward toward the Canadian Maritimes. The low moved over Nova Scotia during the afternoon of 7 September before turning east-northeastward, passing over southern Newfoundland early on 8 September. After moving offshore just east-northeast of St. John's, Newfoundland, the low-level circulation became ill-defined as it merged with a second frontal boundary. Shortly thereafter, another low, which may have contained a portion of Hanna formed along the front and became a very powerful low pressure area over the north Atlantic.

b. Meteorological Statistics

Observations in Hanna (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB). Microwave satellite imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA Aqua, the NASA QuikSCAT, the Department of Defense WindSat, and Defense Meteorological Satellite Program (DMSP) satellites were also useful in tracking Hanna. Eight reconnaissance missions by the U.S. Air Force Reserve and one by the NOAA Aircraft Operations Center were flown into Hanna. The NOAA G-IV aircraft conducted two synoptic surveillance missions. Observations from these missions include flight-level winds, dropwindsonde observations, and surface wind estimates from the Stepped-Frequency Microwave Radiometer (SFMR). WSR-88D radars along the east coast of the United States were also useful in tracking Hanna.

Reconnaissance data on 1 September helped to determine that Hanna attained hurricane strength. The 75 kt estimated peak intensity at 0000 UTC 2 September is partially based on a peak 850 mb flight-level wind of 90 kt that was measured during the afternoon of 1 September. Using a standard flight-level to surface wind reduction, this yields a surface wind estimate of 72 kt. An unofficial surface observing site on Pine Cay in the Caicos Islands measured a minimum pressure of 978.9 mb (Table 3) around 0000 UTC 2 September, which was 4-5 mb lower than the minimum pressure reported by the aircraft earlier in the afternoon.

The 60 kt intensity estimate at the time of landfall in the United States is based on a peak 850 mb flight-level wind of 72 kt and an SFMR surface wind measurement of 58 kt. The SFMR did record an isolated higher peak surface wind of 67 kt at 2339 UTC 5 September, however this estimate appears to have been inflated by heavy rainfall and not considered representative of the maximum sustained surface wind. The estimated minimum pressure of 981 mb at landfall in the United States is based on a minimum pressure of 981.9 mb reported at 0726 UTC 6 September from an unofficial site at Sunset Beach, North Carolina (Table 3).

Selected ship reports of winds of tropical storm force associated with Hanna are given in Table 2. Selected buoys that recorded winds of tropical storm force or greater in association with Hanna are provided in Table 3.

Selected surface observations from land stations and data buoys are given in Table 3. The highest sustained wind measured in the Caicos Islands was 54 kt, which was recorded at the unofficial site on Pine Cay. Unfortunately, the height and exposure of this anemometer are unknown, so it is unclear as to how representative this observation is of the actual wind experienced at that location. Sustained tropical storm force winds were reported at a few observing sites along the coast of the Carolinas and Mid-Atlantic region of the United States. The highest wind reported in the United States was 53 kt with a gust of 63 kt at the Johnny Mercer Pier on Wrightsville Beach, North Carolina.

Although rainfall amounts received from the southeastern Bahamas (Table 3) were relatively low (about 1-3 in), Hanna produced very heavy rainfall over Hispaniola and Puerto Rico as its center passed just north and northwest of those islands. Figure 5 shows that an area of 7 in or greater rainfall occurred over interior sections of Puerto Rico. Most of this rain was recorded between 1-3 September as Hanna's outer rain bands moved across the island. The maximum rainfall reported in Puerto Rico was 16.19 in near Adjuntas and the maximum in the Dominican Republic was 14.17 in at Oviedo. Storm total rainfall amounts from Haiti have not been received as of this writing.

Hanna produced a large swatch of 3-5 in of rain over the eastern United States (Fig. 6). Some areas more directly along Hanna's path received 5-7 in totals, with a maximum amount of 9.65 in at Woodbridge, Virginia. The extratropical remnant of Hanna produced 3-5 in of rain over southern Maine, southern Newfoundland, and portions of Nova Scotia. The highest rainfall total observed in southeastern Canada was 5.72 in at Saint John, New Brunswick.

Hanna produced one EF-1 tornado in the United States that touched down around 1900 UTC 6 September near Allentown, Pennsylvania.

c. Casualty and Damage Statistics

Damage from Hanna appears to have been relatively minor in the southeastern Bahamas and the Turks and Caicos Islands. It should be noted, however, that damage assessments from the southeastern Bahamas and Turks and Caicos Islands were limited after the passage of Hanna, since the same area was struck by major Hurricane Ike less than a week later. A situation report from the Caribbean Disaster Emergency Response Agency (CDERA) on 3 September indicates that wind damage was mostly minor, with some roof damage to homes reported. In addition, considerable flooding was reported in Five Cays and Providenciales. The report also mentioned that several roads suffered damage from storm surge flooding, including major damage to a recently completed causeway linking North and Middle Caicos Islands. There were also reports of boats in and near the Caicos Islands that were washed ashore or sunk during the storm. No casualties were reported in the Bahamas or Turks and Caicos Islands from Hanna.

Heavy rainfall that occurred in Haiti as Hanna passed just north of the north coast of that island on 2-3 September was responsible for severe flooding and an estimated 500 fatalities. The heavy rains exacerbated the flooding situation caused by Tropical Storm Fay and Hurricane Gustav that passed near or over Haiti during the preceding 2-3 weeks. Although significant flooding occurred over much of Haiti, the hardest hit areas were in the northwestern portions of the country, particularly the city of Gonaives. Due to the flooding from the previous storms, and the subsequent impacts of Hurricane Ike the following week, it is difficult to determine the exact death toll in Haiti attributable to Hanna. Reports from the Haitian Red Cross indicate that 793 people perished from the four storms and that about 500 people died in Gonaives, most likely the result of the flooding rains from Hanna. Several hundred people remain missing from the storms and a final death toll from each of the storms will likely never be known.

In the mountainous regions of Puerto Rico, heavy rainfall produced a few mud slides that damaged some roads and bridges. Strong winds in some of the heavier squalls downed a few trees and power lines. There were no reports of injuries or deaths from Hanna in Puerto Rico.

In the United States, Hanna produced an estimated $80 million in insured losses according to the Property Claim Services of the Insurance Services Office, Inc. Using a doubling of insured losses to obtain the total damage gives an estimate of $160 million in damage. The damage over the eastern United States included downed trees and powerlines, which resulted in numerous electrical disruptions. There were some reports of trees that fell on homes, but there were no injuries or deaths as a result. Storm surge flooding in southeastern North Carolina caused minor beach erosion and some flooding in low-lying areas along the Pamlico River. Heavy rainfall produced minor flooding and some road closures along much of the east coast of the United States. More significant flooding was reported in some localized areas such as in Manchester, New Hampshire, where damage was estimated at about $3 million. One indirect drowning death occurred in Georgetown County, South Carolina, when an automobile left the roadway and ended up in a flooded drainage ditch.

The remnants of Hanna were responsible for producing power outages and numerous reports of flooding in southeastern Canada. Media reports indicate that some roads were washed out in southern New Brunswick and Nova Scotia.

d. Forecast and Warning Critique

The tropical wave from which Hanna formed was first mentioned in the Tropical Weather Outlook (TWO) at 1200 UTC 22 August, a little more than five days prior to development. Most of the TWOs issued during the next few days accurately indicated that upper-level winds would inhibit development. The TWO issued at 0000 UTC 26 August, 48 h prior to genesis, was the first to indicate that conditions would become more conducive for development. However, the explicit mention of tropical depression formation did not occur until about the time that the system was designated a tropical cyclone in the final best track.

A verification of official and guidance model track forecasts is given in Table 4. Average official track errors for Hanna were 45, 83, 112, 125, 171, 201, and 213 n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. The number of forecasts ranged from 38 at 12 h to 20 at 120 h. These errors are greater than the average long-term official track errors through 72 h, but are lower than the 5-yr averages at 96- and 120-h. The dynamical model guidance also had large forecast errors, and the only dynamical model that consistently outperformed the official forecast through 72 h was the interpolated ECMWF model (EMXI). The official forecasts exhibited a fairly significant northwestward bias, having not accurately predicted Hanna's southward motion or cyclonic loop on 2-3 September (Fig. 7). The dynamical guidance also had difficulty forecasting Hanna's motion near the Turks and Caicos Islands. However, the GFDL and HWRF models should be commended for at least forecasting a small cyclonic loop to north of the Turks and Caicos Islands.

Average official intensity errors were 5, 9, 11, 14, 15, 9, and 12 kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. For comparison, the average long-term official intensity errors are 7, 10, 12, 14, 18, 20, and 22 kt, respectively. The NHC intensity forecast errors were generally smaller than the 5-yr mean, except at 48 h where they were nearly equal to the long-term average. The official intensity forecasts did not accurately predict that Hanna would reach hurricane strength over the Caicos Islands, since most of the forecasts during that time anticipated little change in strength due to the effects of vertical wind shear. In fairness, however, it should be noted that Hanna was not able to maintain hurricane strength for very long and quickly weakened. Intensity forecasts prior to Hanna reaching the east coast of the United States had a high bias. In fact, official forecasts about three days prior to landfall in the Carolinas predicted that Hanna would reach the coast as a category 2 hurricane.

Watches and warnings associated with Hanna are given in Table 5. A hurricane watch was issued at 0900 UTC 4 September from Edisto Beach, South Carolina, to Surf City, North Carolina, while a tropical storm warning for the area where Hanna made landfall was issued at 2100 UTC that day. This resulted in a lead time for Hanna's landfall of about 46 h for the hurricane watch and about 34 h for the tropical storm warning.

e. Acknowledgements

The Meteorological Services of the Bahamas and the Dominican Republic provided rainfall data for their respective counties. Chris Fogarty of the Canadian Hurricane Center furnished surface data for the extratropical portion of Hanna's life cycle. The National Data Buoy Center and the National Weather Service Offices along the east coast of the United States and in Puerto Rico supplied surface data and storm summaries. David Roth of the Hydrometeorological Prediction Center contributed additional rainfall information.

Table 1. Best track for Hurricane Hanna, 28 August-7 September 2008.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 0000	19.4	57.3	1007	30	tropical depression
28 / 0600	19.7	57.8	1004	30	"
28 / 1200	20.1	58.6	1003	35	tropical storm
28 / 1800	20.5	59.6	1003	35	"
29 / 0000	20.8	60.5	1001	40	"
29 / 0600	20.9	61.5	1000	45	"
29 / 1200	21.1	62.4	1000	45	"
29 / 1800	21.5	63.4	1000	45	"
30 / 0000	21.7	64.5	1000	45	"
30 / 0600	21.8	65.5	1000	45	"
30 / 1200	21.9	66.2	1000	45	"
30 / 1800	22.2	66.9	1000	45	"
31 / 0000	22.6	67.5	999	50	"
31 / 0600	23.1	68.5	999	45	"
31 / 1200	23.5	69.8	999	40	"
31 / 1800	23.6	71.0	997	40	"
01 / 0000	23.5	71.7	997	45	"
01 / 0600	23.2	72.0	996	50	"
01 / 1200	22.8	72.2	990	60	"
01 / 1800	22.3	72.4	985	70	hurricane
02 / 0000	21.8	72.3	977	75	"
02 / 0600	21.4	72.7	980	65	"
02 / 1200	21.0	73.0	983	60	tropical storm
02 / 1800	20.6	72.9	985	55	"
03 / 0000	20.4	72.6	988	55	"
03 / 0600	20.2	72.4	991	50	"
03 / 1200	20.6	71.9	996	45	"
03 / 1800	21.6	71.8	994	50	"
04 / 0000	22.7	71.8	989	55	"
04 / 0600	23.4	72.4	990	60	"
04 / 1200	24.1	73.2	989	55	"
04 / 1800	25.1	74.3	989	55	"
05 / 0000	26.1	75.8	987	55	"
05 / 0600	27.2	77.3	984	55	"
05 / 1200	28.2	78.5	980	55	"
05 / 1800	29.9	78.7	980	60	"
06 / 0000	31.5	79.3	980	60	"
06 / 0600	33.4	78.8	981	60	"
06 / 1200	35.7	78.1	985	45	"
06 / 1800	37.8	76.7	993	45	"

07 / 0000	40.0	74.5	994	45	"
07 / 0600	41.9	71.7	995	45	extratropical
07 / 1200	43.8	68.0	995	45	"
07 / 1800	45.7	63.7	995	45	"
08 / 0000	47.0	59.1	996	40	"
08 / 0600	47.5	55.4	996	40	"
08 / 1200	47.8	52.1	996	35	"
08 / 1800					merged with front
02 / 0000	21.8	72.3	977	75	maximum wind, minimum pressure, and landfall near Providencials Island, Caicos Islands
03 / 1900	21.7	71.8	994	50	landfall near Middle Caicos Island
06 / 0720	33.8	78.7	981	60	landfall near North Carolina / South Carolina border

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Hanna, 28 August-7 September 2008.

Date/Time (UTC)	Ship/Buoy ID	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
01/1500	WDB325	20.3	71.9	200/38	1005.1
01/1900	KCGH	20.7	73.3	250/38	1011.0
03/1700	KCGH	19.7	69.7	180/38	998.0
04/0900	WJBJ	26.9	72.0	070/44	1001.0
04/1200	VQBW2	28.0	70.3	090/35	1006.5
04/1600	WJBJ	25.9	70.5	150/36	1003.2
04/1800	WJBJ	25.3	70.2	160/37	1004.3
04/1900	KIRH	24.1	74.8	270/37	995.3
05/0000	KIRH	25.1	75.7	270/52	991.9
05/0400	C6PT7	26.4	79.0	280/35	1000.0
05/0600	KIRH	25.7	77.2	240/37	996.0
05/0600	C6TZ8	27.6	80.0	360/42	1010.0
05/1000	C6FM8	26.2	79.9	230/43	1009.0
05/1800	WFKW	29.9	80.6	220/40	999.2
05/1800	WNDP	34.0	76.2	150/36	1009.0
06/1500	WPKD	33.3	74.7	190/40	1010.0
06/1800	WPKD	33.0	75.5	230/37	1010.0
06/1800	WNDP	36.1	75.0	190/36	1005.5
06/1800	WPGK	36.9	72.2	160/37	1010.0
06/2100	DGAF	38.2	74.3	200/43	996.5
06/2100	WMVF	38.6	74.9	180/40	996.8
07/0000	A8IY6	38.1	73.0	230/45	1003.0
07/0000	C6FT7	41.1	71.4	100/39	1004.0

Table 3. Selected surface observations for Hanna, 28 August-7 September 2008.

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)			
Caicos Islands								
Meteorological Assimilation Data Ingest System (MADIS)								
Pine Cay (DW0758) (Weather Underground IPINECAY2)	01/2356	978.9	02/0216	54[e]	56[e]			
Pine Cay (MD0758)	02/0012	979.6	02/0233	50				
Bahamas								
Provided by Bahamas Meteorological Service								
Inagua Island (Pump #1)								1.43
Inagua Island (Pump #3)								2.54
Inagua Island (Pump #4)								1.77
Inagua Island (Y-2)								2.48
Inagua Island (G. Hill)								2.12
Inagua Island (P. Point)								1.80
Inagua Island (Y. House)								2.12
Inagua Island (N. Dam)								2.07
Puerto Rico								
USGS and Cooperative Observer Program (COOP)								
Adjuntas (2 ESE)								16.19
Saltillo								14.43
Rio Icacos								12.45
Quebrada								11.19
Rio Mameyes								11.13
Barrio Apeadero								10.02
Sabana Grande								9.76
El Portal								9.55

Rio Tanama								9.08
Rio Bauta								7.20
Rio Guanajibo								5.69
Rio Grande De Loiza San Lorenzo								5.24
Dominican Republic								
Provided by Dominican Republic Meteorological Service								
Oviedo								14.17
Pednernales								10.79
Polo								8.99
San Jose Ocoa								8.78
Las Americas								8.54
Villa Vasquez								8.02
Los Llanos								7.97
Hato Mayor								7.65
La Descubierta								7.57
Bani								7.51
La Romana								6.84
Monte Plata								6.78
Punta Cana								6.53
Bayaguana								6.42
Aerop. Joaquin B.								6.10
Florida								
National Ocean Service (NOS)								
Fernandina Beach (FRDF1)	05/1930	1002.8	05/1518	24	43			
Georgia								
NOS								
Fort Pulaski (FPKG1)	06/0012	1002.3	06/0224		29	2.26	4.77	

South Carolina								
International Civil Aviation Organization (ICAO) and Remote Automated Weather Stations (RAWS)								
Florence Regional Airport (KFLO)	06/0653	997.3	06/0637	21	37			4.53
Myrtle Beach Grandstand (KMYR)	06/0635	988.5	06/0735	25	36			4.28
North Myrtle Beach (KCRE)	06/0653	984.2	06/0643	27	46			
Charleston International Airport (KCHS)	06/0456	998.9	05/1718	19	27			3.54
NOS								
MROS1 – Springmaid Pier SC 33.7°N 78.9°W	06/0836	987.1	06/0148	36	42	3.50	7.25	
Oyster Landing						2.20	6.63	
COOP and Community Collaborative Rain, Hail & Snow Network (CoCoRaHS)								
McClellanville 33.08N 79.46W								4.97
McClellanville (0.5 ESE) 33.08N 79.45W								4.47
Mount Pleasant (8NNE) 32.89N 79.481W								4.42
McClellanville (0.2 ESE) 33.08N 79.46W								4.41
Mount Pleasant (5.7 NE) 32.85N 79.79W								4.32
Huger (3 NNE) 33.13N 79.78W								4.30
Mount Pleasant (4.1 NE) 32.83N 79.81W								4.14
Mount Pleasant (2.5 SW) 32.76N 79.89W								4.07
North Carolina								
ICAO								
Laurinburg Maxton Airport (KMEB)	06/0852	996.1	06/0552	25	35			
Raleigh Durham International Airport (KRDU)	06/1151	995.5	06/1333	16	28			4.77
Fayetteville Regional Airport/Grannis Field (KFAY)	06/0953	991.7	06/0953	23	35			4.62
Simmons AAF	06/1018	993.0	06/1158	28	38			

Seymour-Johnson AFB (KGSB)	06/1051	987.1	06/1049	32	45			
Rocky-Mount Wilson Airport (KRWI)	06/1253	988.3	06/1609	17	34			
Horace Williams Airport (KIGX)	06/1056	997.5	06/1247	18	37			
Beaufort Airport (KMRH)	06/1027	998.9	06/1406	36	48			1.08
New Bern (KEWN)	06/1111	995.5	06/1122	31	49			0.81
Frisco Airport (KHSE)	06/1204	1001.9	06/1144	37	47			1.04
Jacksonville Airport (KOAJ)	06/1043	993.5[f]	06/1002	37[f]				1.32
Wilmington International (KILM)	06/0853	993.2	06/0953	27	47			
Lumberton (KLBT)	06/0854	992.1	06/0844	30	40			4.60
Southport (KSUT)	06/0740	992.5	06/0940	29	49			
Whiteville (KCPC)	06/0820	986.1	06/0940	16	30			
Elizabeth City USCG (KECG)	06/1554	999.7	06/1654	32	46			
Edenton (KEDE)			06/1517	32	42			
RAWS								
Sunny Point (SUNN7) 34.00°N 77.96°W			06/0418	28	49			
Back Island (BKIN7) 34.53°N 77.72°W			06/1118	19	50			
Nature Conservancy (NATN7) 34.05°N 78.29°W			06/0818	21	46			
Turnbull Creek (TURN7) 34.68°N 78.58°W			06/0818	15	40			
Whiteville (WHIN7) 34.34°N 78.73°W			06/0918	12	42			
NOS								
Johnny Mercer Pier (JMPN7) Wrightsville, NC 34.2°N 77.8°W	06/0836	993.1	06/0912	53	63	2.5	5.45	
Wilmington						5.00	6.75	
Ocean Isle Beach						4.00	7.00	
Beaufort						2.00	3.20	
Oregon Inlet (ORIN7)	06/1354	1004.1	06/1742	39	51	2.40	3.40	
Public Report								
Sunset Beach (Weather Underground)	06/0726	981.9	06/0607		37			
Wrightstville Beach NC 34.22°N 77.79°W			06/0700	37	58			
Southport 33.92°N 78.04°W			06/0600	29	37			

Surf City NC 34.4°N 77.57°W			06/0230	36	51			
COOP and CoCoRAHs								
Goldston (4 N) 35.7°N 79.3°W								6.28
Fort Bragg 35.1°N 79.0°W								6.19
Durham (1 NW) 36.0°N 78.9°W								5.33
Raeford 35.0°N 79.2°W								6.29
Emit 35.7°N 78.3°W								5.42
Southern Pines 35.2°N 79.4°W								6.68
Whispering Pines 35.3°N 79.4°W								6.60
Hillsborough (4 SSW) 36.0°N 79.1°W								5.61
Laurinburg 34.8°N 79.5°W								5.74
Laurinburg (8 N) 34.9°N 79.5°W								5.76
Fuquay-Varina (3 NE) 35.6°N 78.8°W								6.00
Raleigh (10 S) 35.7°N 78.6°W								5.21
Apex (3.5 W) 35.7°N 78.9°W								6.02
Apex (1.5 E) 35.7°N 78.8°W								5.00
Cary 35.8°N 78.8°W								5.05
Apex 35.7°N 78.8°W								5.17
Virgina								
ICAO and RAWS								
Quantico Marine Corps Base (KNYG)	06/1856	997.3	06/2005	24	36			
Reagan National Airport (KDCA)	06/1852	998.2	06/1937	27	36			3.90
Manassas Municipal Airport (KHEF)	06/1855	1000.0	06/1740	30	38			
Warrenton Airport (KHWY)	06/1800	1000.3	06/1740	21	34			2.89
Shannon Aiport /Fredericksburg (KEZF)	06/1840	999.3	06/2000	26	35			
Richmond International Airport (KRIC)	06/1654	996.8	06/1907	22	35			

Norfolk International Airport (KORF)	06/1851	998.7	06/1836	29	41			
Newport News/Patrick Henry (KPHF)	06/1654	994.4	06/1554	24	37			
Wallops Island (KWAL)	06/1954	995.4	06/1910	34	47			
Langley AFB (KLFI)		999.9	06/2032	22	36			
Norfolk NAS (KNGU)	06/1653	996.8	06/1353	26	41			
Oceana NAS (KNTU)	06/1656	998.2	06/1156	26	41			
Wakefield Airport (KAKQ)	06/1554	994.2	06/1931	13	29			2.34
James City/Williamsburg Airport (KJGG)			06/1620	22	40			
Accomack Airport (KMFV)			06/1722	25	44			
Fort Belvoir (KDAA)	06/1903	998.3	06/2116	18	30			5.96
Leesburg (KJYO)								5.23
NOS								
Cape Henry (CHYV2) 36.91°N 75.78°W	06/1642	996.1	06/1636	40	53			
Money Point (MNPV2) 36.78°N 76.30°W	06/1606	996.9	06/1330	25	40	0.74	2.78	
Dominion Terminal (DOMV2) 36.96°N 76.42°W	06/1624	994.6	06/1636	36	47			
Kiptopeke (KPTV2) 37.17°N 75.99°W			06/1706	38	50	1.08	3.32	
Yorktown USCG Station (YKTV2) 37.23°N 76.48°W	06/1712	993.8	06/1236	28	38	1.76	3.26	
York River Range Light (YRKV2) 37.25°N 76.33°W	06/1718	993.6	06/1330	43	54			
Rappahannock Light Tower (RPLV2) 37.54°N 76.02°W	06/1812	993.4	06/1806	42	50			
Lewisetta VA (LWTV2) 38.00°N 76.47°W	06/1854	993.8	06/1424	35	43	2.04	2.92	
Wachapreague (WAHV2) 37.61°N 75.69°W	06/1848	996.3	06/1754	38	52	1.36	5.74	
Vienna						2.55	4.00	
COOP and CoCoRaHS								
Woodbridge (2.6 SSW) 38.58°N 77.28°W								9.65
Manassas 38.74°N 77.48°W								7.78
Oakton 38.89°N 77.30°W								8.29
Fairfax City 38.85°N 77.30°W								8.33

Arlington 38.87°N 77.10°W								7.93
Fredericksburg 38.29°N 77.49°W								7.02
Sterling 39.00°N 77.43°W								7.00
Quantico 38.52°N 77.29°W								5.58
Public								
Willoughby Degaussing 36.96°N 76.33°W	06/1518	994.9	06/1536	40	50			
District of Columbia								
NOS								
Washington DC (WASD2) 38.87°N 77.02°W	06/1845	998.2	06/2148	21	27	3.50	4.10	
Maryland								
ICAO and RAWS								
Baltimore/Washington International Airport (KBWI)	06/2054	998.1	06/1540	25	36			1.72
Washington Dulles Airport (KIAD)	06/1952	1000.7	06/1945	26	35			5.42
Andrews AFB (KADW)	06/1940	997.2	06/2029	26	34			2.26
Martin State Airport (MTN)	06/2045	998.6	06/2245	20	28			
U.S. Naval Academy (KNAK)	06/1954	996.9	06/1554	22	41			1.89
Patuxent River NAS (KNHK)	06/1852	994.2	06/1523	28	39			1.70
St. Inigoes (KNUI)	06/1853	993.3	06/1443	22	33			1.97
Leonardtown (K2W6)	06/1907	994.2	06/1431	19	32			
Salisbury-Wicomico Airport (KSBY)	06/1954	994.8	06/1738	27	39			
Ocean City Airport (KOXB)	06/2053	995.3	06/2335	19	38			
NOS								
Piney Point (PPTM2) 38.13°N 76.53°W			06/2200	35	43			
Baltimore MD (BLTM2) 39.27°N 76.58°W	06/2106	997.7	06/2112	27	35	1.80	2.20	
Francis Scott Key Bridge (FSKM2) 39.22°N 76.53°W	06/2106	996.8	06/2030	29	37			
Bishops Head (BISM2) 38.22°N 76.04°W	06/1906	992.6	06/1800	33	44	2.73	3.90	

Cambridge (CAMM2) 38.57°N 76.07°W	06/1954	994.0	06/2342	24	38	3.08	4.36	
Ocean City Inlet (OCIM2) 38.32°N 75.09°W	06/2118	995.5	06/1854	33	46			
McCreadys Creek 38.3°N 76.0°W						2.97	4.31	
COOP and CoCoRaHS								
Potomac 39.02°N 77.20°W								6.23
Nanjemoy 38.45°N 77.22°W								5.00
Gaithersburg 39.14°N 77.22°W								5.22
Delaware								
ICAO and RAWS								
Georgetown/Sussex (KGED)	06/2054	994.6	06/1547	23	38			2.07
Dover (KDOV)	06/2137	994.7	06/1525	23	38			1.25
Wilmington (KILG)	06/2109	996.6	06/2100	23	29			3.32
COOP and CoCoRaHS								
Newark								3.69
Glasgow								3.33
Bear								3.22
Hockessin								3.13
New Jersey								
ICAO and RAWS								
Newark International Airport (KEWR)	07/0151	998.4	07/0047	30	39			3.75
Millville (KMIV)	06/2140	994.5	06/1930	20	36			
Atlantic City (KACY)	06/2254	995.3	06/2050	24	37			2.89
Teterboro (KTEB)	07/0151	998.2	07/0034	18	33			4.10
COOP and CoCoRaHS								
River Edge 40.92°N 74.04°W								5.50
West Paterson 40.88°N 74.19°W								5.32
East Brunswick								5.00
Morris Plains								6.00
Public Reports								
Brant Beach 39.62°N 74.18°W			06/2250	28	43			

Avalon 39.09°N 74.74°W	06/2229	993.6	06/2020	32	46			
Ocean Grove 39.36°N 74.44°W	07/0119	994.9	06/2010	25	44			
Atlantic City 40.20°N 74.01°W			06/2220	23	42			
Pennsylvania								
COOP and CoCoRaHS								
Fredericksville								4.52
New York								
ICAO and RAWS								
Islip (KISP)	07/0456	999.5	07/0430	22	32			
Westhampton Beach (KFOK)	07/0353	996.1	07/0530	22	32			
Shirley/Brookhaven (KHWV)	07/0356	996.0	07/0556	22	34			
Newburg (KSWF)								2.86
Montauk Airport (KMTP)	07/0454	996.3	07/0654	15	26			
Laguardia Airport (KLGA)	07/0151	997.2	06/2141	23	38			3.29
New York Kennedy Airport (KJFK)								2.89
Central Park (KNYC)	07/0151	997.9	06/2147	14	24			3.54
White Plains (KHPN)	07/0156	997.9	07/0256	20	32			4.42
COOP and CoCoRaHS								
New City 41.15°N 73.99°W								5.92
Connecticut								
ICAO and RAWS								
Hartford/Brainard (KHFD)	07/0453	999.1	07/0351	20	31			4.55
Willimantic (KIJD)	07/0452	998.2	07/0652	15	27			
Bridgeport/Sikorski (KBDR)	07/0252	997.3	07/0343	25	33			2.90
Groton (KGON)	07/0456	995.8	07/0203	26	34			2.76
New Haven (KHVN)	07/0253	997.6	07/0351	20	30			3.31
Meriden (KMMK)	07/0253	998.9	07/0403	17	34			3.89
COOP and CoCoRaHS								
New Canaan 41.14°N 73.49°W								6.45
Danbury 41.40°N 73.47°W								6.22

Brookfield 41.46°N 73.42°W								5.43
East Hartford 41.76°N 72.61°W								6.19
Windsor Locks 41.92°N 72.34°W								5.23
Staffordsville 41.98°N 72.28°W								5.95
Rhode Island								
ICAO and RAWS								
T.F. Green Airport (KPV)	07/0551	996.0	07/0218	25	35			
Newport (KUUU)	07/0553	995.9	07/0825	21	36			
Westerly State Airport (KWST)	07/0553	996.1	07/0253	18	28			
NOS								
Conimicut Light (CPTR1)	07/0600	994.5	07/0136	38	48			
Providence (FOXR1)	07/0142	995.3	07/0800	30	37	2.00	4.90	
Quonset (QPTR1)	07/0600	994.8	07/0130	27	34			
COOP and CoCoRaHS								
Warren 41.71°N 71.27°W								5.59
Coventry 41.68°N 71.65°W								5.03
Massachusetts								
ICAO and RAWS								
Nantucket Airport (KACK)	07/0753	996.8	07/0556	27	36			
Bedfords Hanscom Airport (KBED)	07/0656	998.7	07/0741	20	35			
Boston Logan Airport (KBOS)	07/0654	996.2	07/0754	22	33			
Beverly Municipal Airport (KBVY)	07/0653	996.3	07/1953	16	32			
Chatham (KCQX)	07/0752	996.4	07/1032	16	33			
New Bedford (KEWB)	07/0653	995.4	07/0408	24	33			
Fitchburg (KFIT)	07/0652	999.9	07/1252	18	33			
Falmouth(Otis) Ang Base (KFMH)	07/0755	995.6	07/0916	20	30			
Hyannis (KHYA)	07/0756	996.0	07/0956	20	31			
Lawrence (KLWM)	07/0654	999.1	07/0654	22	32			
East Milton/Blue Hill Observatory (KMQE)	07/0654	997.2	07/0754	21	37			
Martha's Vineyard (KMVY)	07/0653	996.0	07/0534	22	33			

Worcester (KORH)	07/0554	999.4	07/0054	20	34			
Norwood (KOWD)	07/0653	996.1	07/0740	16	23			
Provincetown (KPVC)			07/1435	14	23			
Plymouth (KPYM)	07/0652	995.6	07/0852	18	36			
Taunton (KTAN)	07/0652	995.1	07/0144	21	35			4.35
COOP and CoCoRaHS								
Southwick 42.05°N 72.77°W								5.40
Agawam 42.06°N 72.62°W								5.25
Brimfield 42.11°N 72.20°W								5.17
Easthampton 42.26°N 72.68°W								5.54
Tyngsboro 42.68°N 71.42°W								5.53
Lowell 42.63°N 71.32°W								5.51
Westford 42.58°N 71.43°W								5.36
Pepperell 42.66°N 71.59°W								5.00
Needham 42.28°N 71.24°W								6.10
Grafton 42.20°N 71.68°W								6.41
Westborough 42.26°N 71.62°W								6.25
Leicester 42.25°N 71.90°W								5.50
New Hampshire								
COOP and CoCoRaHS								
Nashua 42.74°N 71.49°W								6.56
Merrimack 42.86°N 71.48°W								6.55
Goffstown 43.01°N 71.60°W								6.18
Bennington 43.00°N 71.93°W								6.12
Hudson 43.00°N 71.93°W								5.60
Wilton 42.84°N 71.74°W								5.57

Buoys and Coastal Marine Automated Network (C-MAN)								
41043– SW Atlantic 21.0°N 67.0°W	30/0750	1002.1	06/0705	31	39			
41046– E of Bahamas 23.9°N 70.9°W	04/0506	993.8	01/1027	43	49			
41047– NE of Bahamas 27.5°N 71.5°W	04/1750	1004.2	04/1350	35	66			
41010– 120 nm E of Cape Canaveral 28.9°N 78.5°W	05/1550	979.6	05/0920	37	49			
41009- 20 nm E Cape Canaveral 28.5°N 80.2°W	05/1320	997.4	05/1620	31	41			
41012– ENE of St. Augustine FL 30.0°N 80.6°W	05/1950	997.9	05/2120	34	45			
SAUF1- St. Augustine 29.9°N 81.3°W	05/2000	1002.8	05/1340	34	41			
SPAG1– Skidaway Institute of Oceanography R2 Tower 31.38°N 80.57°W			05/2132	43	51			
41008– Grays Reef 31.4°N 80.9°W	05/2150	1000.9	05/1800	31	39			
SKMG1– Skidaway Institute of Oceanography M2R6 Tower 31.53°N 80.24°W	06/0135	999.8	06/0135	37	43			
41004– Edisto 32.5°N 79.1°W	06/0350	982.3	06/0410	40	51			
FBIS1- Folly Beach SC 32.68°N 79.89°W	06/0400	998.9	05/0800	23	29			
41029 – Caro Coops Capers Nearshore Buoy 32.81°N 79.63°W	06/0400	987.8	06/0200	32	37			
41013– Frying Pan Shoals 33.4°N 77.7°W	06/0650	995.1	06/0650	41	52			
41038– 5 SE Wrightsville Beach NC 34.1°N 77.7°W	06/1000	991.8	06/1000	35	51			
41036– Onslow Bay 34.2°N 77.0°W	06/0850	999.5	06/0740	38	49			
41035– Onslow Bay 34.5°N 77.2°W	06/0950	996.8	06/1120	39	56			
CLKN7– Cape Lookout NC 34.6°N 76.5°W	06/1000	1002.0	06/1000	39	46			
41025– Diamond Shoals 35.0°N 75.4°W	06/1050	1004.8	06/1220	36	49			
DUCN7– Duck Pier NC 36.2°N 75.8°W	06/1212	1001.6		38				

44014– E of Virginia Beach 36.6°N 74.8°W	06/1850	1003.0	06/1900	37	47			
CHLV2– Chesapeake VA Light 36.9°N 75.7°W	06/1700	996.3	06/1740	45	54			
Jamestown VA (Chesapeake Bay Interpretive Buoy System (CBIBS) 37.20°N 76.78°W	06/1700	993.8	06/1840	25	37			
Stingray Point VA (CBIBS) 37.55°N 76.25°W	06/1750	993.2	06/1720	33	40			
CAMM2 – Cambridge MD 38.56N 76.08W	06/1954	994.0	06/2324	24	38			
LWSD1 – Lewes DE 38.78N 75.15W	06/2130	993.8	07/0018	32	38			
44009– Delaware Bay 38.5°N 74.7°W	06/2050	994.9	06/2050	37	45			
BRND1 – Brandywine Shoal Light DE 38.89N 75.11W	06/2130	994.0	06/2048	33	49			
TPLM2– Thomas Point 38.9°N 76.4°W	06/2100	996.7	06/1500	33	47			
CMAN4 – Cape May NJ 38.94N 74.97W	06/2206	994.1	06/1954	25	39			
SJSN4 – Ship John Shoal NJ 39.12N 75.25W	06/2142	994.6	06/1748	37	50			
TCBM2 – Tolchester MD 39.12N 76.25W	06/2030	996.4	06/2148	33	42			
44025– S of Long Island 40.25°N 73.17°W	07/0150	995.1	07/0050	33	39			
SDHN4 – Sandy Hook NJ 40.44N 73.99W			07/0300	23	32			
44017– SW of Montauk Point 40.7°N 72.0°W	07/0350	995.7	07/0150	29	37			
44008– SE of Nantucket 40.5°N 69.4°W	07/0750	999.1	07/0610	33	43			
44018– E of Nantucket 41.3°N 69.3°W	07/0850	997.0	07/0650	29	37			
44013– E of Boston 42.3°N 70.7°W	07/0750	995.3	07/0850	34	41			
44039– Central Long Island Sound 41.14°N 72.66°W	07/0423	996.5	07/0523	27	37			
44040– Western Long Island Sound 40.96°N 73.58°W	07/0215	998.2	07/0319	23	31			
44060– Eastern Long Island Sound 41.26°N 72.07°W	07/0515	996.1	07/0215	25	33			
LDLC3– New London Ledge 41.31°N 72.08°W	07/0515	995.3	07/0730	33	43			

IOSN3– Isle of Shoals 43.0°N 70.6°W	07/0800	997.7	07/0750	39	51			
Weatherflow								
Virginia Beach Pier VA 36.84°N 75.97°W	06/1645	997.2	06/1450	40	50			
Cape Henry VA 36.92°N 76.01°W	06/1645	994.3	06/1640	36	46			
Lynnhaven Pier/Virgina Beach VA 36.92°N 76.08°W	06/1650	994.8	06/2030	30	37			
Little Creek/Norfolk VA 36.93°N 76.18°W	06/1630	994.3	06/1705	35	45			
Lafayette River/Norfolk VA 36.89°N 76.32°W	06/1635	995.7	06/1630	31	41			
Monitor Merrimac Bridge Tunnel VA 36.94°N 76.40°W	06/1635	993.8	06/1655	34	45			
Hampton Flats/Hampton VA 36.98°N 76.35°W	06/1635	994.3	06/1635	35	45			
Thimble Shoals/ Chesapeake Bay VA 37.05°N 76.26°W	06/1645	996.2	06/1540	38	46			
3rd Island Bay Bridge Tunnel VA 37.03°N 76.08°W	06/1635	990.5	06/1640	48	59			
Messick Point VA 37.11°N 76.32°W	06/1700	994.8	06/1140	35	43			
New Point Comfort VA 37.33°N 76.27°W	06/1730	993.4	06/1720	38	48			
Plantation Flats/Cape Charles VA 37.26°N 76.03°W	06/1710	996.2	06/1715	40	48			
Silver Beach VA 37.49°N 75.97°W	06/1810	993.4	06/1855	38	44			
Deltaville VA 37.56°N 76.30°W	06/1755	992.9	06/2225	20	31			
Great Wicomico Light VA 37.80°N 76.27°W		991.5	06/1440	36	46			
Tangier Island VA 37.78°N 75.99°W	06/1850	993.4	06/1605	36	47			
Onanock VA 37.66°N 75.87°W	06/1835	993.8	06/2135	38	47			
Crisfield MD 37.97°N 75.88°W	06/1905	992.4	06/1810	36	47			
Raccoon Point MD 38.14°N 75.79°W	06/1930	991.9	06/2235	27	38			
Bishops Head MD 38.22°N 76.04°W	06/1920	991.0	06/1805	37	48			
Ocean City MD) 38.33°N 75.08°W	06/2020	992.9	06/2035	32	57			

Assateague Island MD 38.21°N 75.20°W	06/2020	994.8	06/2000	30	48			

[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).
[e] Incomplete data. Data missing on 2 September between 0323 and 1706 UTC.
[f] Incomplete data.

Table 4. Track forecast evaluation (heterogeneous sample) for Hurricane Hanna, 28 August-7 September 2008. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	63 (39)	139 (37)	219 (35)	286 (33)	396 (29)	488 (25)	546 (21)
GFNI	52 (35)	92 (33)	124 (31)	140 (29)	192 (25)	234 (22)	287 (18)
GFDI	54 (39)	95 (37)	126 (35)	147 (33)	201 (29)	259 (25)	265 (21)
HWFI	50 (39)	91 (37)	124 (35)	153 (33)	198 (29)	266 (25)	345 (21)
GFSI	48 (39)	86 (37)	121 (35)	150 (33)	208 (29)	278 (25)	311 (20)
AEMI	49 (39)	86 (37)	117 (35)	137 (33)	**152 (27)**	**148 (21)**	**189 (17)**
NGPI	50 (39)	95 (37)	131 (35)	155 (33)	216 (29)	257 (25)	292 (21)
UKMI	47 (36)	88 (34)	116 (32)	125 (30)	**161 (26)**	247 (22)	351 (18)
EGRI	48 (36)	89 (34)	117 (32)	127 (30)	**162 (26)**	248 (22)	375 (18)
EMXI	**41 (28)**	**65 (27)**	**76 (25)**	**94 (24)**	**150 (21)**	**176 (18)**	**199 (16)**
BAMD	**43 (39)**	**67 (37)**	**83 (35)**	**98 (33)**	**143 (29)**	201 (25)	217 (21)
BAMM	46 (39)	**75 (37)**	**97 (35)**	**118 (33)**	**158 (29)**	**186 (25)**	**207 (21)**
BAMS	69 (38)	116 (36)	153 (34)	181 (32)	220 (29)	253 (25)	299 (21)
LBAR	47 (38)	84 (36)	119 (34)	155 (32)	222 (29)	300 (25)	370 (21)
TVCN	45 (39)	**81 (37)**	**108 (35)**	127 (33)	**167 (29)**	220 (25)	242 (21)
GUNA	46 (36)	83 (34)	**109 (32)**	**121 (30)**	**155 (26)**	**192 (22)**	**200 (18)**
FSSE	48 (36)	85 (35)	112 (33)	132 (31)	180 (27)	230 (23)	240 (18)
OFCL	45 (38)	83 (36)	112 (34)	125 (32)	171 (28)	201 (24)	213 (20)
NHC Official (2003-2007 mean)	34.0 (1742)	58.2 (1574)	82.2 (1407)	106.2 (1254)	154.2 (996)	207.5 (787)	272.5 (627)

Table 5. Intensity forecast evaluation (heterogeneous sample) for Hurricane Hanna, 28 August-7 September 2008. Forecast errors (kt) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
OCD5	6.7 (39)	9.2 (37)	**10.9 (35)**	**11.9 (33)**	**9.7 (29)**	**9.0 (25)**	12.0 (21)
GHMI	6.9 (39)	9.4 (37)	14.9 (35)	19.5 (33)	27.0 (29)	23.2 (25)	22.2 (21)
HWFI	6.3 (39)	9.5 (37)	12.8 (35)	16.3 (33)	22.2 (29)	17.8 (25)	15.1 (21)
LGEM	6.9 (39)	9.0 (37)	**10.9 (35)**	**11.6 (33)**	**12.4 (29)**	11.5 (25)	15.0 (21)
DSHP	6.8 (39)	9.5 (37)	11.8 (35)	**12.8 (33)**	15.3 (29)	14.9 (25)	16.5 (21)
FSSE	6.9 (36)	10.1 (35)	13.3 (33)	**14.3 (31)**	17.2 (27)	18.7 (23)	23.0 (18)
ICON	6.2 (39)	**8.4 (37)**	**10.5 (35)**	**12.6 (33)**	17.4 (29)	16.3 (25)	16.5 (21)
OFCL	5.1 (38)	8.5 (36)	11.2 (34)	14.4 (32)	14.6 (28)	9.2 (24)	12.0 (20)
NHC Official (2003-2007 mean)	6.7 (1742)	10.0 (1574)	12.3 (1407)	14.3 (1254)	18.2 (996)	19.7 (787)	21.8 (627)

Table 6. Watch and warning summary for Hurricane Hanna, 28 August-7 September 2008.

Date/Time (UTC)	Action	Location
30/1500	Tropical Storm Watch issued	Southeast Bahamas and Turks and Caicos
31/0900	Tropical Storm Watch changed to Tropical Storm Warning	Turks and Caicos
31/1500	Tropical Storm Watch changed to Tropical Storm Warning	Southeast Bahamas
31/1500	Tropical Storm Watch issued	Central Bahamas
31/2100	Tropical Storm Watch changed to Tropical Storm Warning	Central Bahamas
01/1500	Hurricane Watch issued	Central Bahamas
01/1800	Tropical Storm Warning changed to Hurricane Warning	Central Bahamas, Southeast Bahamas, and Turks and Caicos
01/1800	Hurricane Watch discontinued	Central Bahamas
02/1500	Tropical Storm Warning issued	N coast of Haiti from Le Mole St. Nicholas to N Haiti/Dominican Republic border
02/2100	Tropical Storm Warning extended	N and W coast of Haiti Port Au Prince to N Haiti/Dominican Republic border
02/2100	Tropical Storm Warning issued	N coast of Dominican Republic from Puerto Plata westward to Bahia de Manzanillo
03/0300	Hurricane Watch issued	Northwest Bahamas
03/2100	Hurricane Watch changed to Hurricane Warning	Northwest Bahamas
03/2100	Hurricane Warning changed to Tropical Storm Warning	Southeast Bahamas and Turks and Caicos
04/0300	Hurricane Warning changed to Tropical Storm Warning	Central and Northwest Bahamas
04/0300	Tropical Storm Warning discontinued	All of Haiti and the Dominican Republic
04/0900	Tropical Storm Watch issued	Altamaha Sound, Georgia to Edisto Beach, South Carolina
04/0900	Hurricane Watch issued	Edisto Beach, South Carolina to Surf City, North Carolina
04/1200	Tropical Storm Warning discontinued	Southeast Bahamas and Turks and Caicos
04/1500	Hurricane Watch extended	Edisto Beach, South Carolina to Ocracoke Inlet, North Carolina

04/2100	Tropical Storm Warning issued	Savannah River, Georgia to North Carolina/Virginia border including Pamlico and Albemarle Sounds
4/2100	Hurricane Watch extended	Edisto Beach, South Carolina to Currituck Beach Light, Virginia including Pamlico Sound
04/2100	Tropical Storm Watch issued	North Carolina/Virginia border to Great Egg Inlet including the Chesapeake Bay, the tidal Potomac, Washington, D.C., and Delaware Bay
05/0900	Tropical Storm Warning modified	Altamaha Sound, Georgia to Chincoteague Virginia including Pamlico and Albemarle Sounds and northward into Chesapeake Bay to Smith Point
05/0900	Tropical Storm Watch extended	Chincoteague, Virginia to Sandy Hook, New Jersey
05/0900	Tropical Storm Watch discontinued	all south of Chincoteague, Virginia
05/1500	Tropical Storm Watch changed to Tropical Storm Warning	Chincoteague, Virginia to Sandy Hook, New Jersey including the Chesapeake Bay, the tidao Potomac, Washington, D.C., and Delaware Bay
05/1500	Tropical Storm Watch extended	Sandy Hook, New Jersey to Watch Hill, Rhode Island
05/1800	Tropical Storm Warning discontinued	Northwest Bahamas
05/2100	Tropical Storm Watch extended	Watch Hill, Rhode Island to Merrimack River, Massachusetts
06/0300	Tropical Storm Watch changed to Tropical Storm Warning	Sandy Hook, New Jersey to Watch Hill, Rhode Island
06/0300	Tropical Storm Warning discontinued	south of Edisto Beach, South Carolina
06/0300	Hurricane Watch discontinued	south of South Santee River, South Carolina
06/0900	Tropical Storm Watch changed to Tropical Storm Warning	Watch Hill, Rhode Island to Merrimack River, Massachusetts
06/0900	Hurricane Watch discontinued	All
06/0900	Tropical Storm Warning discontinued	south of South Santee River, South Carolina
06/1200	Tropical Storm Warning discontinued	south of Cape Fear, North Carolina
06/1500	Tropical Storm Warning discontinued	south of Surf City, North Carolina
06/1800	Tropical Storm Warning discontinued	south of Cape Hatteras, North Carolina

06/2100	Tropical Storm Warning discontinued	south of the North Carolina/Virginia border
07/0000	Tropical Storm Warning discontinued	south of Cape Henlopen, Delaware
07/0300	Tropical Storm Warning discontinued	south of Sandy Hook, New Jersey
07/0600	Tropical Storm Warning discontinued	south of Watch Hill, Rhode Island
07/0900	Tropical Storm Warning discontinued	all

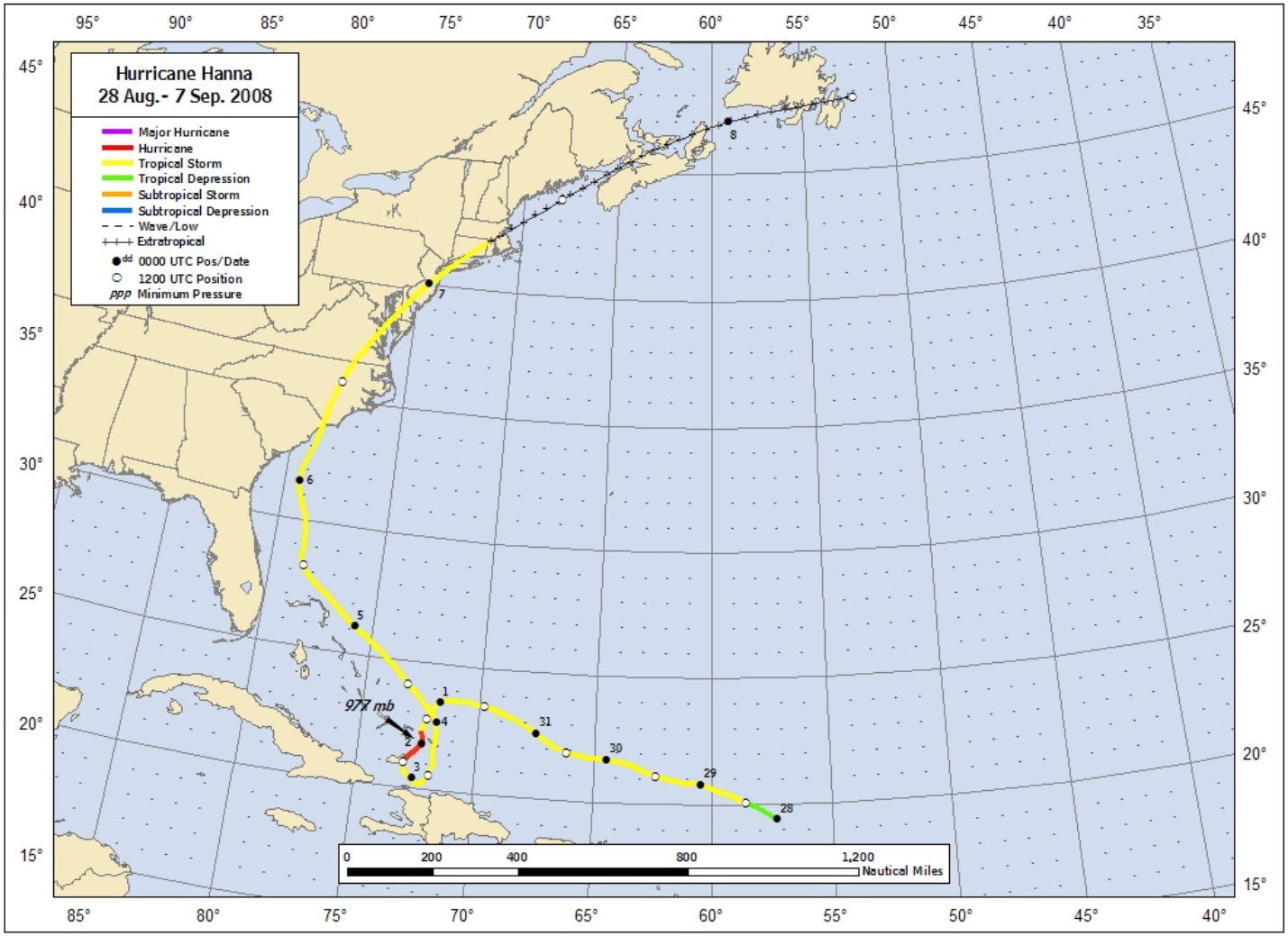


Figure 1. Best track positions for Hurricane Hanna, 28 August-7 September 2008. Track during the extratropical stage is based partially on analyses from the NOAA Ocean Prediction Center and the Canadian Hurricane Center.

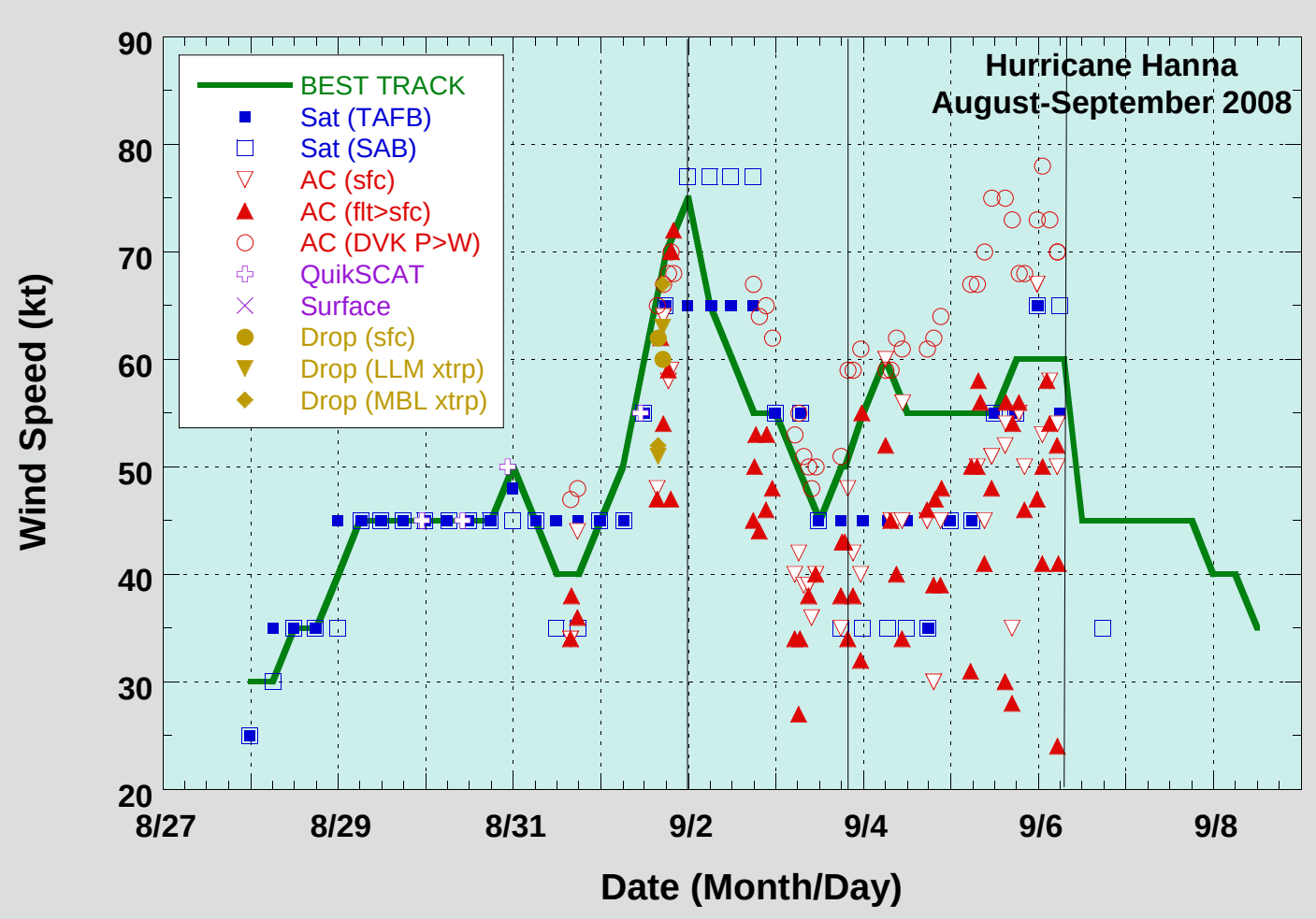


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Hanna, 28 August-7 September 2008. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM), and from the sounding boundary layer mean (MBL). Estimates during the extratropical stage are based on analyses from the Ocean Prediction Center and the Canadian Hurricane Center. Dashed vertical lines correspond to 0000 UTC. Thin solid vertical lines denote landfalls.

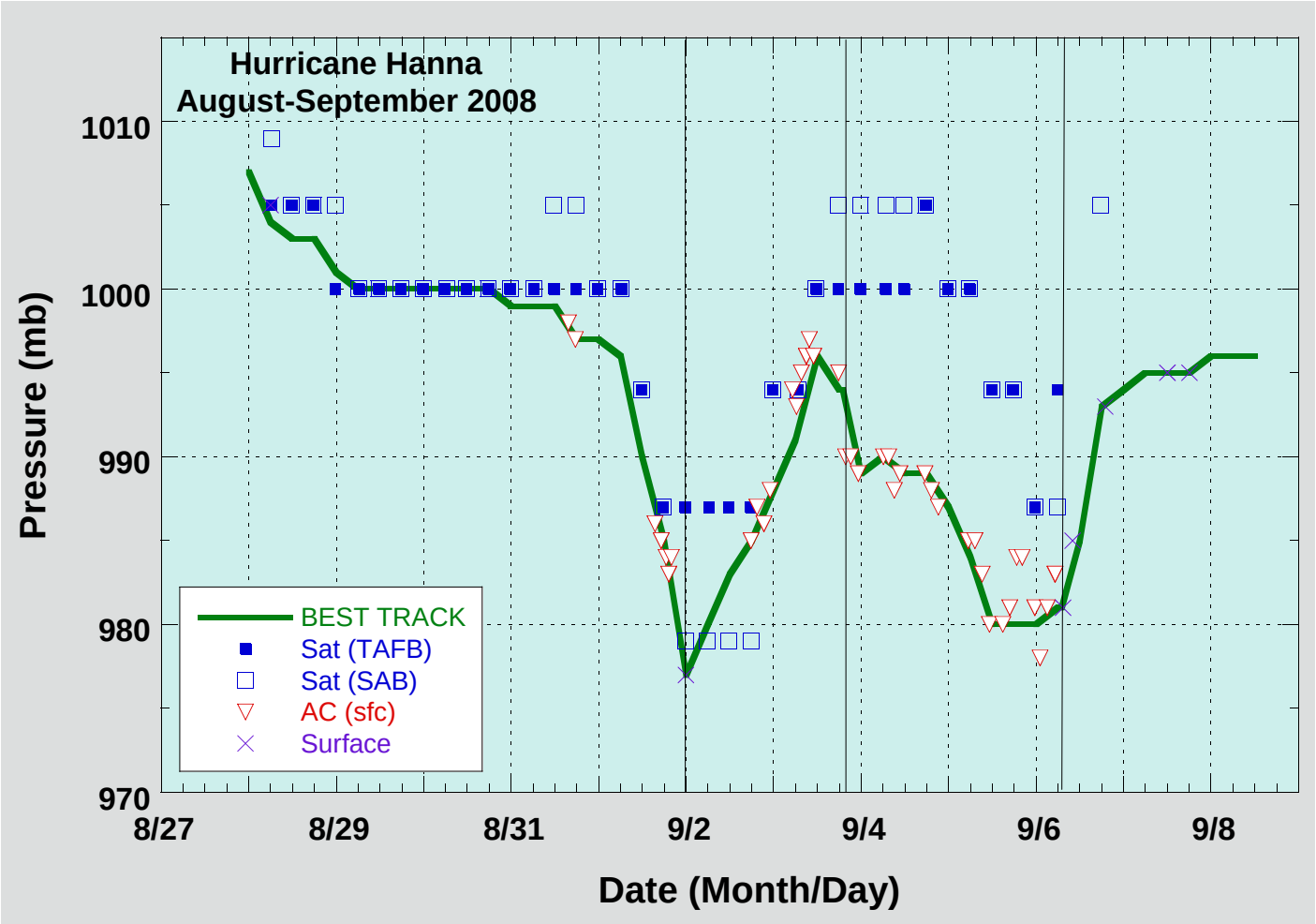


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Hanna, 28 August-7 September 2008. Estimates during the extratropical stage are based on analyses from the Ocean Prediction Center and the Canadian Hurricane Center. Dashed vertical lines correspond to 0000 UTC. Thin vertical lines denote landfalls.

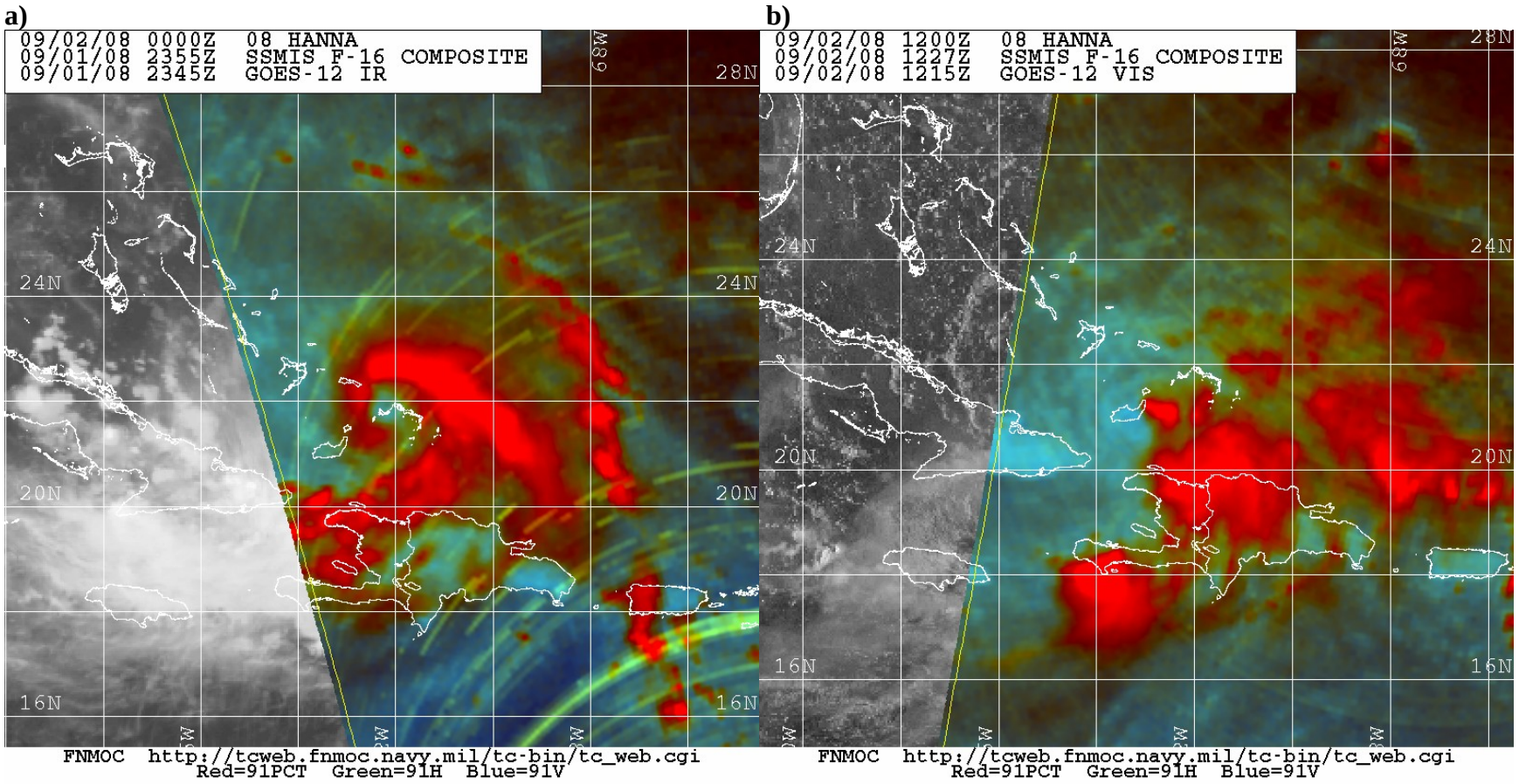


Figure 4. Composite 91 GHz passive microwave images showing Hanna near peak intensity (a) and 12 h later (b). Note the banding eye-feature seen in the first image and how the convection is displaced to the south and east of the low-level center (located near Great Inagua Island in the southeastern Bahamas) just 12 h later. Images courtesy of the Fleet Numerical Meteorology and Oceanography Center (FNMOC).

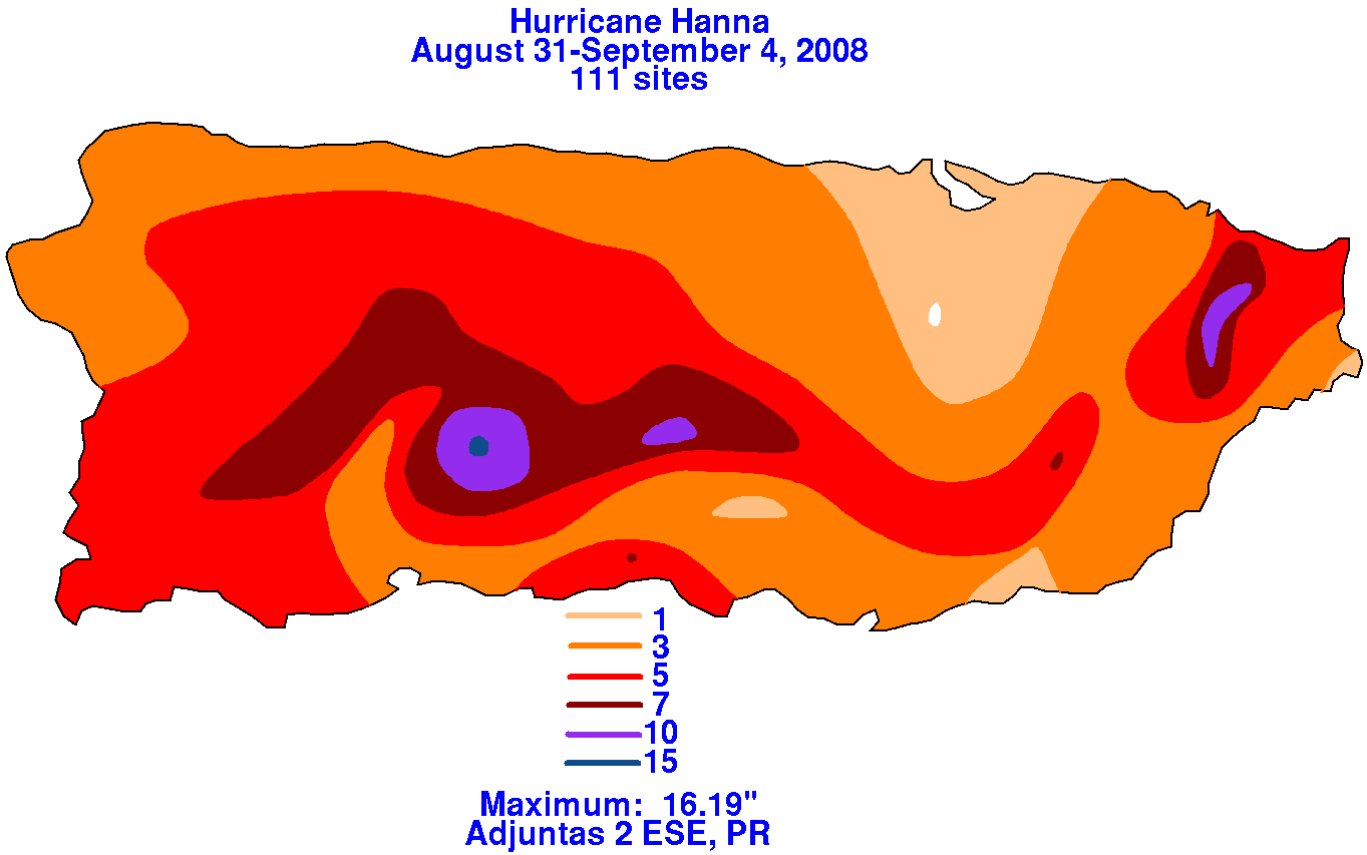


Figure 5. Rainfall associated with Hanna over Puerto Rico. Image courtesy of the Hydrometeorological Prediction Center.

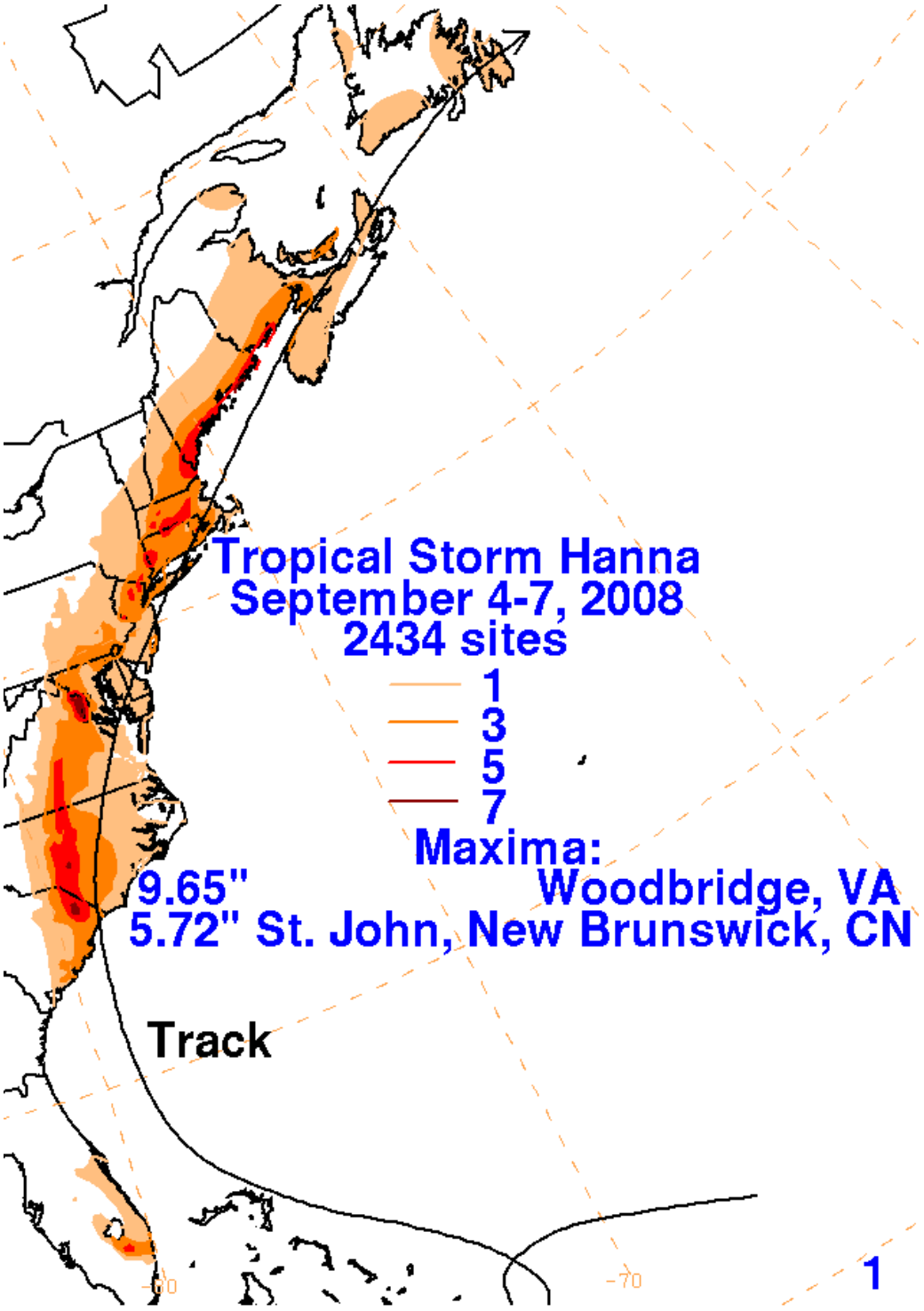
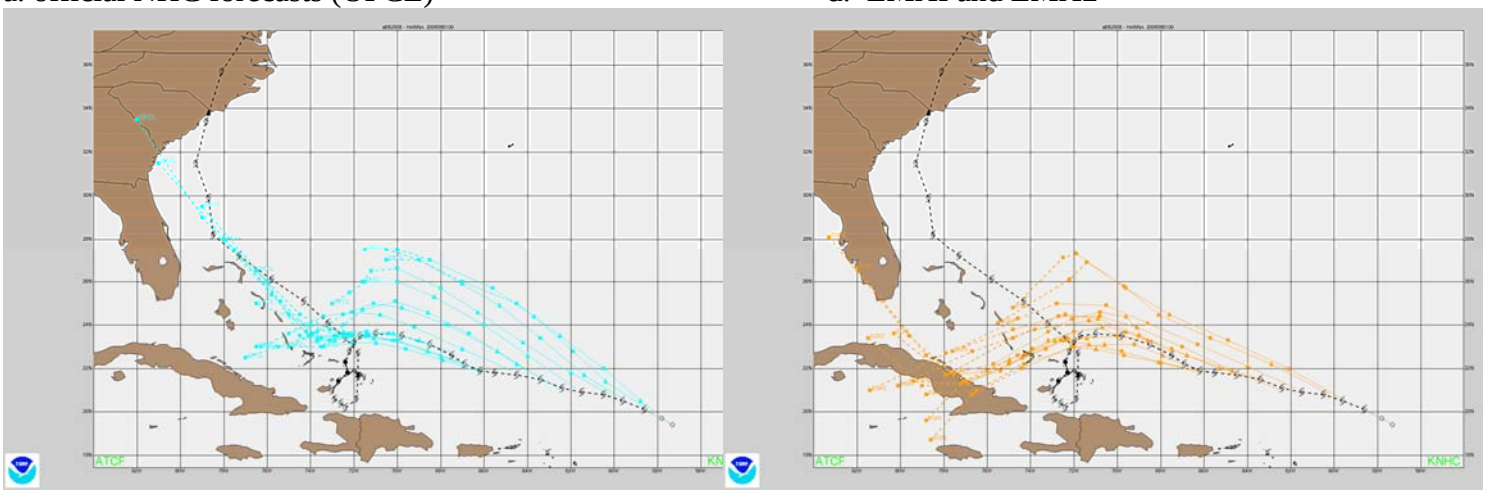


Figure 6. Rainfall associated with Hanna over the eastern United States and southeastern Canada. Image courtesy of the Hydrometeorological Prediction Center.

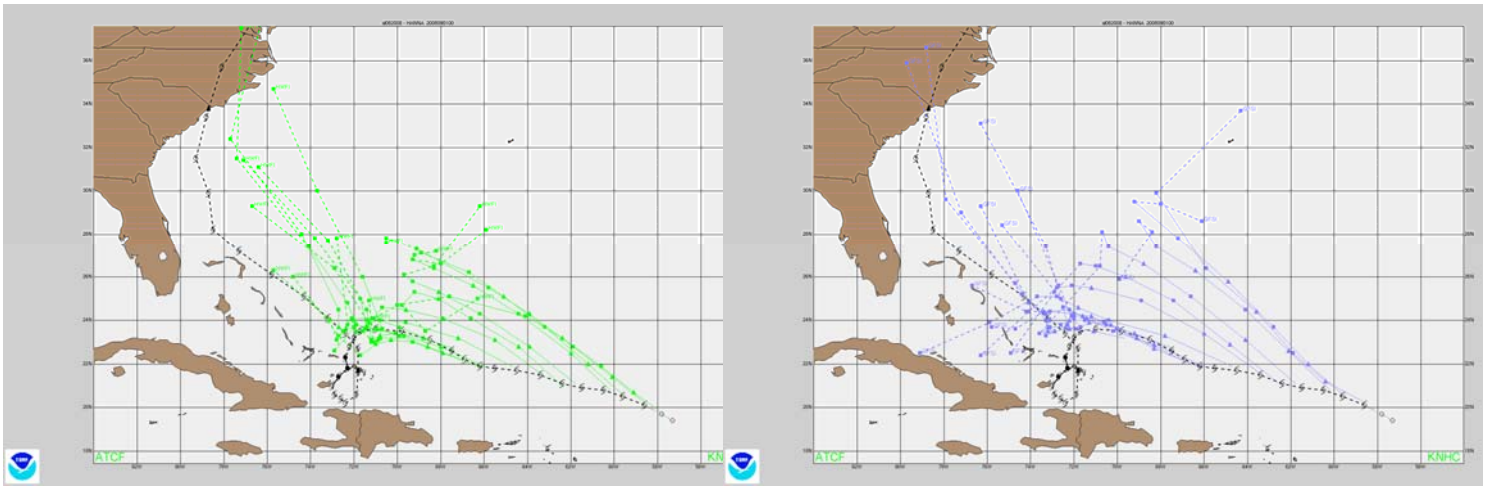
a. official NHC forecasts (OFCL)

d. EMXI and EMX2



b. HWFI

e. GFSI



c. GFDI

f. UKMI and UKM2

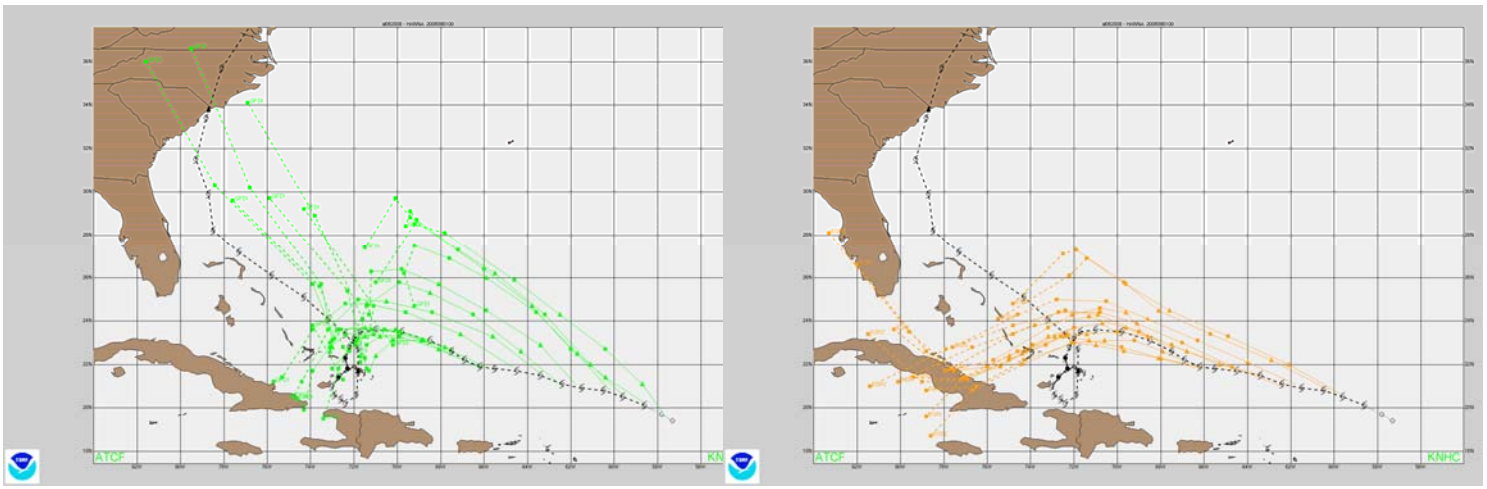


Figure 7. Official NHC and model track forecasts from 0600 UTC 28 August to 0000 UTC 1 September. Note that neither the NHC official forecasts (OFCL) nor any of the individual track models predicted Hanna's cyclonic loop that occurred on 2-3 September. The GFDI model (c), however, did predict a more southward turn toward eastern Cuba or the Windward Passage than the remainder of the guidance forecast.