Tropical Cyclone Report
Hurricane Irene
(AL092011)
21-28 August 2011

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Irene hit Crooked, Acklins and Long Island in the Bahamas as a category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) but gradually weakened after crossing the Bahamas. It made landfall in North Carolina as a category 1 hurricane and caused widespread damage across a large portion of the eastern United States as it moved north-northeastward, bringing significant effects from the mid-Atlantic states through New England. The most severe impact of Irene in the northeastern United States was catastrophic inland flooding in New Jersey, Massachusetts and Vermont.

a. Synoptic History

Irene originated from a vigorous tropical wave that exited the west coast of Africa on 15 August, accompanied by a large area of cloudiness and thunderstorms. The convection diminished when the wave moved just south of the Cape Verde Islands the next day, but the wave maintained a well-defined mid-level circulation. Showers and thunderstorms gradually regenerated while the wave continued westward across the tropical Atlantic, and the cloud pattern became better organized by the time the system was halfway between the west coast of Africa and the Lesser Antilles on 17 August. A reconnaissance aircraft investigated the system for several hours on 20 August, finding surface winds of 40-45 kt but no well-defined closed low-level circulation. Finally, just before the conclusion of the mission, the aircraft was able to "close off" a circulation near the southern edge of the convection about 120 n mi miles east of Martinique, marking the formation of a tropical storm shortly before 0000 UTC 21 August. The "best track" chart of Irene'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].

After genesis, Irene moved toward the west-northwest across the extreme northeastern Caribbean Sea, gaining organization and strength as the circulation became larger on 21 August. As the center of the cyclone moved over St. Croix around 2300 UTC that day, (Fig.4) an interval

[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.

of light winds associated with the center was observed, and in fact, an Air Force Reserve Hurricane Hunter aircraft was able to depart for its mission during that period of calm.

Irene continued west-northwestward and the center passed over the eastern shore of Puerto Rico at 0535 UTC 22 August. The cyclone became a hurricane while moving over the island a short time later, but the hurricane-force winds occurred only over water north of the center and did not affect the island. The hurricane moved very close to the north coast of Hispaniola on 23 August, and despite a favorable atmospheric environment of low shear, the interaction of Irene's circulation with the high terrain of Hispaniola likely delayed additional intensification. As it moved away from Hispaniola early on 24 August, however, Irene began to strengthen. It became a category 3 hurricane on the Saffir-Simpson Hurricane Wind Scale, with a peak intensity of 105 knots and a minimum central pressure of 957 mb, at 1200 UTC 24 August when it was centered between Mayaguana and Grand Inagua in the Bahamas. The eye was then about 18 n mi in diameter, as reported by the meterologist on board the hurricane hunter plane. The hurricane continued moving west-northwestward, crossing Acklins and Crooked Islands near 1500 UTC 24 August, and these islands likely experienced category 3 hurricane conditions. Irene weakened a little bit when it moved over Long Island around 0000 UTC 25 August.

A mid-tropospheric trough developed over the eastern United States on 24 August, and the subtropical ridge that had been steering Irene west-northwestward across the southeastern Bahamas shifted eastward. Embedded within the associated flow pattern, Irene turned toward the north-northwest and north as it moved across the central and northwestern Bahamas. The eye passed between Exuma and Cat Island around 0600 UTC 25 August, crossed Eleuthera a few hours later, and then reached the Abaco Islands in the northwestern Bahamas around 1800 UTC 25 August. By then, Irene had weakened further and these islands probably experienced category 2 hurricane conditions. Although Irene's winds decreased during this period and the eye became less discernible in satellite images, its circulation expanded and the central pressure continued to fall, reaching 942 mb by 0600 UTC 26 August.

Figure 5 shows the evolution of Irene's inner core from near the time of the peak intensity to the time of lowest pressure. The center panel shows a rainband in the northeast quadrant outside the eyewall that could have been the beginning of an eyewall replacement cycle (which ultimately did not complete). In addition, the radial wind profile became very broad, consistent with the less defined banding pattern shown in Fig. 5b and c; reconnaissance data indicate that during 26 – 27 August, the radius of hurricane-force winds expanded and reached 80 n mi in the northeast quadrant. Note in Fig. 2 that after Irene reached its peak intensity at 1200 UTC 24 August, the normal Dvorak wind/pressure relationship (represented by the open circles) suggests stronger winds than what was observed. This is probably related to the larger than normal size of the cyclone and the absence of a particularly intense inner core.

The hurricane continued northward and passed well offshore from the east coast of Florida and Georgia while weakening. Irene made landfall near Cape Lookout, North Carolina at 1200 UTC 27 August with an intensity of 75 kt, producing category 1 hurricane-force winds within a swath primarily to the east of the center over the North Carolina sounds and the Outer Banks. Irene then continued north-northeastward, just offshore of the Delmarva peninsula, and made another landfall very near Atlantic City, New Jersey, at Brigantine Island, at 0935 UTC 28 August. Although Irene's intensity at the New Jersey landfall was 60 kt, winds of that strength were confined to the waters east of the track of the center. Irene continued moving north-northeastward and the center moved over Coney Island, Brooklyn, New York around 1300 UTC 28 August, and then over Manhattan, New York City about 1 h later. Once again, the storm's strongest winds at the time of landfall (55 kt) continued to occur primarily well to the east of the center. Irene moved north-northeastward over the northeastern United States and became extratropical when its center was near the New Hampshire/Vermont border around 0000 UTC 29 August. The cyclone was then absorbed at 0600 UTC 30 August over northeastern Canada by a frontal system.

b. Meteorological Statistics

Irene was well sampled by reconnaissance aircraft. There were 19 missions performed by the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command and 16 by the National Oceanic Administration Agency (NOAA) Aircraft Operations Center WP-3D aircraft. The aircraft observations included flight-level winds, stepped frequency microwave radiometer (SFMR) surface wind estimates, dropwindsonde data and Doppler radar observations, as well as center "fixes". There were also seven missions involving the NOAA G-IV high-altitude jet to sample the surrounding environment.

Other data sources during Irene included Coastal Marine Automated Network (CMAN) stations, National Ocean Service (NOS) stations, NOAA ocean buoys, and ships. The U.S. National Weather Service rawindsonde network considerably expanded its routine launches to provide additional data for input to numerical forecast models. Ship reports of tropical-storm-force winds associated with Irene are listed in Table 2, and selected surface observations from land stations and data buoys are given in Table 3 and Figure 6.

Satellite observations also assisted with the analysis of Irene's history. These include subjective Dvorak technique intensity and position estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective intensity Dvorak estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison (UW-CIMSS). In addition, it was very important to include microwave data and imagery from NOAA polar-orbiting satellites, including UW-CIMSS Advanced Microwave Sounding Unit (AMSU) intensity estimates, Defense Meteorological Satellite

Program (DMSP), and National Aeronautics and Space Administration (NASA), including the Tropical Rainfall Measuring Mission (TRMM), and the European Space Agency's Advanced Scatterometer (ASCAT).

National Weather Service WSR-88D radars from San Juan, Puerto Rico, and near the coast from the Carolinas to the mid-Atlantic states, as well as FAA radars were used to make center fixes, observe the storm's structure, and obtain velocity data. Surface observations provided by the Dominican Republic and the Bahamas Weather Services were very useful in constructing the best track in those areas.

There were unconfirmed reports of wind gusts of 100 kt in Moss Town, Exuma and in Arthur's Town on Cat Island around 0600 UTC 25 August. Eleuthera reported a minimum pressure of 952.4 mb at 0900 UTC 25 August as the eye moved near that island, and Marsh Harbor in the Abacos measured a minimum pressure of 950.4 mb at 1700 UTC 25 August. These pressures are very similar to those reported by a reconnaissance aircraft at those times. An automatic weather station at West End in Grand Bahama reported sustained winds of 79 kt at 0100 UTC 26 August. The Bahamas Weather Service is in the process of recovering data from their automatic stations for analysis and verification.

The analyzed maximum wind speed of 105 kt at 1200 UTC 24 August is based on a 700-mb flight-level peak wind of 116 kt at 1430 UTC that day, measured by a hurricane hunter aircraft in the northeastern eyewall. After the time of this peak wind observation, the closed eyewall structure changed to a more fractured feature, and the strong flight-level winds were no longer penetrating down to the surface sufficiently to support the maintenance of a 105-kt intensity. In fact, the minimum central pressure continued to drop for another 15 h, to 942 mb at 0600 UTC 26 August (as measured by a dropsonde) but by then, Irene's estimated intensity decreased to 90 kt.

Shortly before the center of Irene moved over New York City, flight-level winds measured by the reconnaissance aircraft would typically have support hurricane intensity at the surface. SFMR and dropsonde data, however, show that the standard flight level to surface wind reduction continued to be inappropriate; the observed surface wind values at that time support a 55-kt intensity. The latest observation to definitively support an analysis of hurricane intensity was an SFMR report of 66 kt well to the east of the center near 0103 UTC 28 August.

Irene produced copious amounts of rain in Puerto Rico, with a maximum of 22.05 inches in Gurabo Abajo, which caused major flooding in the northeastern portion of the island. In addition, Irene produced a large swath of 5 to 10 inches of rain along the east coast of the mainland United States and nearby inland areas from North Carolina northward. The maximum rainfall amount observed was 15.74 inches in Bayboro, North Carolina, as indicated in Fig. 7 and Table 3.

Irene was a large hurricane, and generated high waves and storm surge over a large portion of the western Atlantic basin for several days. The highest storm surge value reported by a tide gage was 7.09 ft at 0354 UTC 28 August at Oregon Inlet Marina, NC. Post storm surveys suggest that a storm surge of 8 to 11 ft occurred within portions of Pamlico Sound. Storm surge values between 4 and 6 ft were measured along the coast from New Jersey northward. Figure 8 shows selected storm surge values associated with Irene. Additional storm surge information can be found from the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) website at http://tidesandcurrents.noaa.gov.

Irene spawned several tornadoes along its path over the eastern United States. The strongest was an EF2 tornado that touched down in Columbia, North Carolina, destroying a few manufactured homes. There were also two EF1 tornadoes in North Carolina, two of unknown intensity in Virginia, two EF0 tornadoes in New York, and one EF1 tornado in Pennsylvania.

c. Casualty and Damage Statistics

Preliminary reports indicate that Irene was directly responsible for 49 direct deaths: 5 in the Dominican Republic, 3 in Haiti, and 41 in the United States. Surprisingly, there were no reported deaths in the Bahamas, where Irene was the strongest. For the United States, 6 deaths are attributed to storm surge/waves, or rip currents, 15 to wind, including falling trees, and 21 to rainfall-induced floods. Additional information on those casualties is given in Table 7.

According to media reports and a summary provided by the Meteorological Service of the Dominican Republic, Irene caused flooding from surge and high waves in low-lying areas and damaged homes in portions of the north coast of the Dominican Republic. Damage from flooding caused by rains was extensive across Puerto Rico and was severe near the area of Gurabo Abajo.

In the mainland United States, Irene caused widespread damage to homes and felled trees from North Carolina northward, and produced extensive power outages. In North Carolina, the flow from the sound to the ocean damaged Highway 12, cutting several breaches. The most severe surge damage occurred between Oregon Inlet and Cape Hatteras, but significant storm surge damage also occurred along southern Chesapeake Bay. In the Hampton Roads area, and along coastal sections of the Delmarva Peninsula from Ocean City, Maryland southward, storm surge flooding was comparable to that from Hurricane Isabel of 2003. In New Jersey and eastern Pennsylvania, Hurricane Irene produced torrential rains that resulted in major flooding and several record breaking crests on rivers. A storm surge of 3-5 ft along the New Jersey shores caused moderate to severe tidal flooding with extensive beach erosion.

Since the strongest winds were over water to the east of the path of the center, New York City escaped severe damage. Nonetheless, a storm surge of 3-6 ft caused hundreds of millions of dollars in property damage in New York City and Long Island. Tropical-storm-force winds along with heavy rains resulted in power outages for up to 3 million residents that lasted to around 1 week, mainly across Connecticut and Long Island. Irene's main impact, however was from rainfall. Catastrophic floods occurred in New York and New England, especially in central and southern Vermont. Widespread rainfall amounts of 4-7 inches occurred across much of southern and central Vermont. These rains caused devastating flash flooding across many mountain valleys with some record breaking flood stages on larger rivers. This flood event will likely rank second to the November 1927 flood, with nearly 2400 roads, 800 homes and businesses, 300 bridges, and a half dozen railroad tracks destroyed or damaged from the flooding in southern Vermont. Three towns in the Catskill Mountains in New York were uninhabitable after the floods.

In the United States, the Insurances Services Office reported that the hurricane caused an estimated $3.5 billion in losses. Doubling this figure in an attempt to account for uninsured losses results in an estimated U. S. damage total of $ 7 billion. There is no figure available from the National Flood Insurance Program yet, which will need to be added to this preliminary estimate. The Government of the Bahamas is currently assessing the damage caused by Irene. A detailed summary of the damage can be found in the post-storm reports of local National Weather Service offices in affected areas.

d. Forecast and Warning Critique

The genesis of Irene was well predicted. The tropical wave from which Irene originated was introduced with a low probability of formation (less than 30%) in the Tropical Weather Outlook at 0000 UTC 18 August, 72 h prior to formation. At this time, the tropical wave was located over the eastern Atlantic. The probability was raised to medium (30-50%) 48 h before genesis and then to the high category (greater than 50%) about 24 h before the tropical cyclone formed.

A verification of NHC official track forecasts for Irene is given in Table 4a. The NHC official mean track errors for Irene were considerably lower than the previous 5-yr average through 96 h, although the climatology and persistence model (OCD5) errors were also lower than normal, which indicates that the track of Irene was easier than average to forecast. Although the initial official forecasts indicated a threat to Florida, from the time Irene entered the southeastern Bahamas late on Tuesday 23 August, the NHC official track forecasts were remarkably consistent and accurate in showing a path offshore from Florida and extreme eastern North Carolina, along or very near the coast of the Mid-Atlantic states, and into the New York

City/Long Island area as noted in Fig. 9. Forecast model guidance began converging on this solution when the NOAA Gulfstream-IV jet began its surveillance missions on the 23 August. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. Both the Global Forecast System (GFS) and the European Center for Medium Range Weather and Forecasting (ECMWF) model had lower mean errors than the official forecast through the entire lifetime of Irene. However, none of the multi-model consensus techniques had lower average track errors.

A verification of the NHC official intensity forecasts for Irene is given in Table 5a. The climatology and persistence model (OCD5) errors were lower than the previous 5-yr averages at all time periods, suggesting that the intensity of Irene was easier to forecast than average. However, official intensity errors for Irene were higher than the mean official errors for the previous 5-yr period at all times. This was the result of a consistent high bias during the U.S. watch/warning period (Fig. 10). The main reason for the high bias in the official forecast was that Irene was anticipated to maintain category 3 intensity through landfall in North Carolina, given that the hurricane was forecast to remain in an environment of relatively light wind shear while moving over a warm ocean. However, Irene surprisingly did not maintain or increase its strength while moving between the Bahamas and North Carolina. Rather, it weakened to a category 1 hurricane (two categories below what was originally anticipated) by the time it made landfall near Cape Lookout. One factor in this weakening could have been an incomplete eyewall replacement cycle (e.g. Fig. 4b). In this case, it appears that after the inner eyewall eroded, the outer eyewall never underwent the typical contraction and so re-strengthening did not occur. Instead, Irene's structure was characterized by a series of rainbands, resulting in a broad and diffuse wind field that slowly decayed. It is important to note that NHC does not have reliable tools to anticipate these structural changes. Developing improved intensity forecast guidance is a top priority of NOAA Hurricane Forecast Improvement Project now in its early stages.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. The NHC intensity errors were generally larger than those of the guidance models available for Irene. The climatology and persistence model (OCD5) errors were generally lower than most of the remainder of the available intensity guidance, indicating a lack of skill in the guidance.

In addition, there was a high bias in the operational analysis of Irene's intensity during much of 25-28 August, the period when the typical surface to flight-level wind ratio did not apply (Fig. 10). There was a reluctance on the part of the forecasters to base the intensity on the lower SFMR winds, when the central pressure and flight-level winds were suggesting that stronger surface winds could become re-established at any time, had the convective structure of the cyclone improved.

Watches and warnings associated with Irene are listed in Table 6. A tropical storm warning was issued for the U.S. Virgin Islands and Puerto Rico at 2300 UTC 20 August, about 29 h before the center of Irene made landfall in Puerto Rico. The tropical storm warning for Puerto Rico was upgraded to a hurricane warning at 1500 UTC 21 August, but the island did not experience hurricane-force winds. A hurricane warning was issued for the U.S. southeast coast from Little River Inlet to the North Carolina/Virginia Border at 2100 UTC 25 August, providing a lead time of 39 h before the center crossed the coast. Watches and warnings were gradually extended northward along the east coast of the United States as indicated in Table 6.

e. Acknowledgments

National Weather Service Forecast offices in Puerto Rico and along the United States east coast provided many of the observations listed in this report. NOAA buoy observations are from the National Data Buoy Center. The Hurricane Specialist Unit at the National Hurricane Center, especially Robbie Berg, provided extensive insight and guidance in the writing of this report. The NHC storm surge unit provided very valuable data for this report. We also thank the Meteorological Services of the Dominican Republic and the Bahamas for their input and data.

Table 1. Best track for Hurricane Irene, 21-28 August 2011.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 0000	15.0	59.0	1006	45	tropical storm
21 / 0600	16.0	60.6	1006	45	"
21 / 1200	16.8	62.2	1005	45	"
21 / 1800	17.5	63.7	999	50	"
22 / 0000	17.9	65.0	993	60	"
22 / 0600	18.2	65.9	990	65	hurricane
22 / 1200	18.9	67.0	989	70	"
22 / 1800	19.3	68.0	988	75	"
23 / 0000	19.7	68.8	981	80	"
23 / 0600	20.1	69.7	978	80	"
23 / 1200	20.4	70.6	978	80	"
23 / 1800	20.7	71.2	977	80	"
24 / 0000	21.0	71.9	969	80	"
24 / 0600	21.3	72.5	965	95	"
24 / 1200	21.9	73.3	957	105	"
24 / 1800	22.7	74.3	954	100	"
25 / 0000	23.5	75.1	952	95	"
25 / 0600	24.1	75.9	950	95	"
25 / 1200	25.4	76.6	950	90	"
25 / 1800	26.5	77.2	950	90	"
26 / 0000	27.7	77.3	946	90	"
26 / 0600	28.8	77.3	942	90	"
26 / 1200	30.0	77.4	947	85	"
26 / 1800	31.1	77.5	950	80	"
27 / 0000	32.1	77.1	952	75	"
27 / 0600	33.4	76.8	952	75	"
27 / 1200	34.7	76.6	952	75	"
27 / 1800	35.5	76.3	950	65	"
28 / 0000	36.7	75.7	951	65	"
28 / 0600	38.1	75.0	958	65	"
28 / 0935	39.4	74.4	959	60	tropical storm
28 / 1200	40.3	74.1	963	55	"
28 / 1300	40.6	74.0	965	55	"
28 / 1800	42.5	73.1	970	50	"
29 / 0000	44.2	72.1	979	45	extratropical
29 / 0600	46.5	69.5	983	40	"
29 / 1200	49.1	66.7	985	40	"
29 / 1800	51.3	63.8	987	40	"
30 / 0000	53.0	60.0	991	40	"
30 / 0600					absorbed

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	landfalls
21 / 2300	17.8	64.6	993	60	St.Croix
22 / 0525	18.1	65.8	990	60	Punta Santiago, P.R.
24 / 1600	22.4	74.0	955	100	Acklins/Crooked Isl., Bahamas
25 /0000	23.5	75.1	952	95	Long Isl.
25 / 0900	24.7	76.2	950	90	Eleuthera
25 / 1800	26.5	77.2	950	90	Abacos
27 / 1200	34.7	76.6	952	75	Cape Lookout, N.C.
28 / 0935	39.4	74.4	960	60	Brigantine Is., N.J.
28 / 1300	40.6	74.0	965	55	Coney Island, Brooklyn
24 / 1200	21.9	73.3	957	105	maximum winds
26 / 0600	28.8	77.3	942	90	minimum pressure

Table 2. Selected ship observations for Hurricane Irene, 21 -28 August 2011.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
21 / 1900	J8AZ3	18.3	64.1	050 / 37	1007.0
22 / 0200	A8LL8	20.7	65.7	060 / 35	1014.0
22 / 1100	KIRH	19.0	66.3	050 / 60	997.5
24 / 0000	WCOB	19.9	70.2	140 / 37	1002.4
26 / 1100	H3GS	29.8	80.7	350 / 40	1002.0
26 / 1300	A8LC2	32.4	79.5	050 / 47	1005.0
27 / 0300	DHDE	33.1	72.0	170 / 40	1008.0
27 / 0900	V2CE9	32.7	69.9	180 / 40	1010.0
27 / 1100	WHDV	30.8	72.8	190 / 35	1006.0
27 / 1200	3FSB4	30.9	78.7	270 / 37	1004.0
28 / 0000	KIRH	36.2	70.5	140 / 44	1002.0
28 / 0100	JCRN4	39.5	74.5	050 / 40	995.0
28 / 0600	SBFC	36.9	67.9	150 / 37	1008.4
28 / 1200	C6VG8	36.0	70.9	180 / 45	1013.0
28 / 1200	SBFC	36.8	68.8	180 / 36	1006.3
28 / 1200	ZCDG8	40.5	67.8	160 / 56	1003.7
28 / 1300	C6TX6	35.3	72.7	160 / 47	998.0
28 / 1800	SBFC	37.2	69.9	190 / 39	1005.1
28 / 1800	IOSN3	43.0	70.6	130 / 41	987.6
28 / 1900	KNBD	42.0	70.1	180 / 51	989.8
28 / 2100	WKAB	40.2	67.3	180 / 37	1005.0
28 / 2300	VCSZ	47.0	70.8	050 / 37	995.6

Table 3. Selected surface observations for Hurricane Irene, 21 -28 August 2011

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)			
Netherlands Antilles								
Saint Eustatius (TNCE)	21/1500	1004.1	21/1500	31	47			
Saint Maarten (TNCM)	21/1800	1006.1	21/1800	27	40			
Dominican Republic								
Punta Cana (MDPC)	22/2100	1000.0	22/2100	20	40			
Puerto Plata (MDPP)	23/1200	991.2	23/0600	50				
Bahamas								
George Town (MYEG)	25/0259	974.0	25/0559	42	60			
Nassau (MYNN)	25/1300	987.5	25/1000	36	54			
West End Grand Bahama	26/0000	995.9	26/0100	79				
United States								
Puerto Rico and the U.S. Virgin Islands								
ICAO Sites								
San Juan, PR (TJSJ)	22/0730	992.3	22/0611	39	51			
St. Thomas, VI (TIST)	21/2143	1004.4	21/2112	40	60			
St. Croix, VI (TISX)	23/0153	997.6	22/0038	38	44			
Roosevelt Roads, PR (TJNR)	22/0458	997.0	22/0054	34	49			
Marine Observations								
Christiansted Harbor, St. Croix, VI (CHSV3)	21/2218	996.5	21/2342	28	63	1.03	1.63	
Lime Tree Bay, St. Croix, VI (LTBV3)	21/2236	996.9	22/0006	37	49	0.80	1.55	
Charlotte Amalie, St. Thomas, VI (CHAV3)	21/2130	1003.7				0.95	1.42	
Lameshur Bay, St. John, VI (9751381)	21/2142	1004.5				0.59	1.32	
Culebra, PR (CLBP4)	22/0512	1004.5	22/0254	20	44	0.64	1.60	
Esperanza, Vieques, PR (ESPP4)	22/0412	996.0	22/0448	51	66	1.62	1.96	
Fajardo, PR (FRDP4)	22/0530	998.4	22/0406	35	53	1.60	2.58	
Yabucoa Harbor, PR (YABP4)			22/0648	26	44	0.95	1.31	
San Juan, PR (SJNP4)	22/0742	992.7	22/0654	35	48	0.86	1.80	

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)			
Public/Other								
Gurabo (GARP4) 18.25 N -65.98 W			22/0545		49			22.09
Canovanos (CNAP4) 18.37 N -65.91 W								20.70
Naguabo (NGHP4) 18.21 N -65.74 W								18.92
San Lorenzo (SLGP4) 18.19 N -65.97 W								18.02
Orocovis (OROP4) 18.22 N -66.39 W								17.84
Luquillo (MSCP4) 18.37 N -65.72 W								17.50
Carolina (TJSJ) 18.40 N -65.98 W								12.25
Ponce (IANP4) 17.98 N -66.61 W								10.09
Fajardo			22/0520		62			
Yubucoa			22/0655		56			
Las Mareas			22/0540		35			
Florida								
Marine Observations								
I-295 Bridge, St. Johns River (8720357)						1.36	2.30	
Mayport (Bar Pilots Dock) (MYPF1)	27/2248	1004.5	26/1212	28		1.38	6.76	
Fernandina Beach (FRDF1)	27/2248	1001.4				1.85	8.70	
Georgia								
Marine Observations								
Fort Pulaski (FPKG1)	27/2042	1000.9	26/1836	26	33	1.15	9.11	
South Carolina								
International Civil Aviation Organization (ICAO) Sites								
Myrtle Beach (KMYR)			26/2123	30	38			
North Myrtle Beach (KCRE)	27/0853	989.5	26/2059	28	43			
Florence (KFLO)	27/0953	997.2	26/1944	28	37			
Georgetown (KGGE)	27/0735	994.9	27/0515	24	36			

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)			
Marine Observations								
Clarendon Plantation (8667633)						1.62	9.94	
Charleston (8665530)	27/0724	998.6	26/1648	30	40	1.44	7.64	
North Inlet Winyah Bay (NIWS1)	27/0545	994.0	27/0600	20				
Springmaid Pier (MROS1)	27/0748	991.0	26/2130	40	54	1.65	7.66	
Oyster Landing (N. Inlet Estuary) (8662245)						2.15	7.53	
North Carolina								
ICAO Sites								
Wilmington (KILM)	27/0953	979.5	27/1101	40	57			
Lumberton (KLBT)	27/1054	993.2	27/1254	24	40			
Southport (KSUT)	27/0915	981.4	27/0935	30	46			
Beaufort (KMRH)	27/1256	951.9	27/1503	46	61			6.31
Frisco (KHSE)	27/1735	970.2	27/1251	51	76			6.77
Manteo (KMQI)			27/1715	35	57			
Cherry Point (KNKT)	27/1254	954.3	27/0854	45	60			
New Bern (KEWN)			27/1154	40	63			
Elizabeth City USCG (KECG)	27/2054	957.1	27/2005	43	64			
Edenton (KEDE)			27/2155	33	49			
Non-Metar Observations								
Back Island (AWSs)	27/1118	985.1	27/1318	27	61			8.33
North Topsail Beach – Marker 3	27/1005	973.9	27/0652	40	50			
North Topsail Beach – Fire Department	27/1025	972.6	27/0652	43	48			
Wrightsville Beach	27/0925	976.6	27/0754	34	51			
Bald Head Island	27/0852	979.0	27/0852	50	59			
Socastee-Schwartz Plant	27/0722	992.2	26/2153	24	39			
Sunset Harbor	27/0939	982.7	27/0908	21	54			
Whiteville	27/0906	990.2	27/0753	29	33			
Wilmington-Kingston Grant	27/0915	978.3	27/1154	23	46			
Cedar Island (CITN7)	27/1400	954.0	27/1050	63	78			

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)			
Swanquarter (SWQN7)			27/1920	59	68			
Cedar Island Ferry			27/1150		100			
Weatherflow Observations								
Fort Macon			27/1510		80			
Buxton			27/1330		70			
Oregon Inlet			27/1220		68			
Salvo			27/1420		67			
Avon Pier			27/1125		67			
Frisco			27/1010		66			
Pamlico Sound			27/1135		74			
Marine Observations								
Wilmington (8658120)	27/0930	979.5				0.14	5.24	
North Carolina Reserve (NOXN7)	27/0915	978.0	26/2230	38				6.20
Johnny Mercer Pier-Wrightsville (JMPN7)	27/0924	976.3	27/0236	49	64	2.11	6.85	
Surf City						3.50	7.00	
Beaufort (BFTN7)	27/1300	952.9	27/0806	35	58	3.03	6.28	
Cape Lookout (CLKN7)	27/1200	953.3	27/1100	58	68			
USCG Station Hatteras (HATN7)	27/1736	968.6	27/0942	50	69	3.66	4.10	
Oregon Inlet (ORIN7)	27/1954	965.5	27/2042	51	70	7.09	7.62	
Duck (DUKN7)	27/2112	950.6	27/2106	61	73	1.82	5.22	
Texas Tech University Tower Observations								
Tower 0103A 35.55 N 75.61 W	27/1100			71*				
Tower 0107A 34.69N 76.67 W	27/1000			69*				
Public/Other								
Bayboro (COOP) 35.14 N -76.77 W								15.74
New Bern (COCORAH) 35.13 N -77.07 W								14.79
Williamston (COCORAH) 35.83 N -77.06 W								14.27
Kinston (COCORAH) 35.24 N -77.51 W								13.61

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)			
Washington (HYDRO) 35.55 N -77.05 W								13.11
Aurora (COOP) 35.30 N -76.79 W								13.10
Havelock (COCORAH) 34.92 N -76.97 W								12.64
Greenville (COCORAH) 35.50 N -77.33 W								12.32
Jacksonville (COCORAH) 34.73 N -77.49 W								11.70
Winterville (COCORAH) 35.50 N -77.33 W								11.20
Pocosin Lakes (HYDRO) 35.74 N -76.51 W								11.20
Croatan Forest (RAWS) 34.76 N -76.89 W								11.13
Trent Woods (COCORAH) 35.05 N -77.09 W								10.94
Maysville (COCORAH) 34.92 N -77.29 W								10.68
Perrytown (COOP) 35.05 N -77.08 W								10.07
Virginia								
ICAO Sites								
Richmond (KRIC)	27/2254	986.6	28/0254	35	61			5.37
Norfolk (KORF)	27/2351	968.2	28/0151	35	49			7.92
Newport News (KPHF)	27/2354	975.0	28/0128	35	52			7.18
Langley AFB (KLFI)	27/2355	973.1	27/2155	37	54			
NAS Norfolk (KNGU)	27/2359	971.0	27/2259	37	51			
Fort Eustis (KFAF)	28/0006	975.7	28/0551	35	52			
James City/Williamsburg (KJGG)			27/2355	21	66			
Reagan National (KDCA)	28/0652	985	28/0454	36	52			3.83
Washington/Dulles (KIAD)	29/0052	998	28/0432	28	44			
Fort Belvoir (KDAA)	28/0558	986	28/0755	27	43			3.36
Manassas (KHEF)			28/0615	25	38			
Warrenton (KHWY)			28/0415	24	38			
Leesburg (KJYO)			28/0735	26	38			

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)			
Non-Metar Observations								
Reston (RSTFM)			28/0615		48			
Lorton (LORTN)			28/0559		43			
Woodbridge (WODBR)			28/0649		43			
Spotsylvania (SPTSY)			27/2130		42			
Fairfax (FORFX)			28/0539		38			
Weatherflow Observations								
Cape Henry	27/0036	963.0	27/1126	48	57			
Little Creek			27/0834	36	41			
Monitor Merrimac Bridge	27/0828	971.0	27/1057	46	57			
Hampton Flats	28/1205	979.0	27/0230	34	49			
3rd Island Chesapeake Bay Bridge Tunnel	27/0755	966.0	28/0415	47	54			
New Point Comfort			27/0803	37	44			
Deltaville	27/0120	991.0	27/0136	41	47			
Tangier Island	27/0115	970.0	27/1150	35	42			
Onancock	27/1138	969.0	27/0100	38	56			
Cobb			28/0110	58	64			
Monroe Creek			28/0415	45	55			
Marine Observations								
Chesapeake Light Tower (CHLV2)	28/0100	959.0	27/2200	51	64			
Chesapeake Bay Bridge Tunnel (CBBV2)	27/2348	967.3	27/1600	51	62	4.14	7.38	
Rappahannock Light Tower (RPLV2)	28/0306	970.1	28/0530	48	57			
York River Range (YRKV2)	28/0106	972.6	27/1812	49	65			
Yorktown USCG (YKTV2)	28/0012	974.7	28/0342	46	57	3.69	6.60	
Willoughby Degaussing Station	27/2336	970.1	27/1612	48	58			
Lewisetta (LWTV2)	28/0406	979.1	28/0824	33	50	2.96	4.54	
Sewells Point (SWPV2)	27/2306	972.0				4.54	7.55	
Money Point (MNPV2)	27/2312	968.5	28/0148	35	54	4.82	8.48	
Windmill Point (8636580)						3.02	4.73	

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)			
Kiptopeke (KPTV2)			28/0448	43	55	3.23	6.49	
Wachapreague (WAHV2)[g]	28/0342	968.1	27/1642	39	57	3.02	6.74	
Jamestown						4.20	6.05	
Public/Other								
Savage 36.49 N -76.60 W								13.96
Conway (NCNR5) 36.37 N -77.20 W								13.30
Windsor (GCRN7) 36.01 N -76.89 W								12.21
Saunders (GDSV2) 36.61 N -76.55 W								11.14
Kilby 36.72 N -76.65 W								10.85
Great Bridge 36.71 N -76.26 W								10.75
Portlock 36.79 N -76.28 W								10.58
Newland 38.05 N -76.87 W								10.50
Conway 36.43 N -77.23 W								10.45
Williamsburg 37.29 N -76.79 W								10.05
Suffolk 36.73 N -76.60 W								9.76
Princess Anne 38.20 N -75.69 W								9.73
Deep Creek 36.74 N -76.34 W								9.72
Maryland								
ICAO Sites								
Baltimore-Washington (KBWI)	28/0654	982.6	28/0354	26	44			
Salisbury (KSBY)	28/0554	971.1	27/2116	40	53			
Ocean City (KOXB)	28/0053	983.7	27/2053	33	47			
Martin State (KMTN)			28/1145	34	48			
Andrews AFB (KADW)			28/0455	34	47			
Annapolis U.S Naval Academy (KNAK)	28/0754	980.9	28/0354	29	45			

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)			
Patuxent River NAS (KNHK)	28/0552	979.3	28/0231	36	56			
Non-Metar Observations								
Chesapeake Beach (CHSRL)			28/0215		63			
Gaithersburg (GTHNT)			28/0559		63			
Baltimore (BLTND)			28/1100		52			
Upper Marlboro (UMLBO)			28/0724		51			
Laurel (LRSHS)			28/0429		50			
Manchester (MNCMG)			28/0805		50			
Rockville (RVSJD)			28/0559		45			
Weatherflow Observations								
Herring Bay			28/0040	41	56			
Tolly Point			28/0220	45	60			
Marine Observations								
Thomas Point (TPLM2)	28/0800	979.6	28/0229	49	62			
Cove Point (COVM2)	28/0600	978.4	28/0024	51	63			
Francis Scott Key Bridge (FSKM2)	28/0724	980.4	28/1100	52	62			
Solomons Island (SLIM2)	28/0618	979.5	28/0336	40	59	2.24	3.69	
Piney Point (PPTM2)			28/0936	47	54			
Bishops Head (BISM2)	28/0542	975.8	28/1024	40	51	2.02	4.14	
Cambridge (CAMM2)	28/0648	976.2	27/2230	38	52	0.80	3.10	
Ocean City Inlet (OCIM2)	28/0624	964.4	28/1236	29	42	2.01	4.69	
Public/Other								
Leonardtown (MD-SM-3) 38.30 N -76.63 W								11.52
Piney Point (MD-SM-1) 38.16 N -76.54 W								10.57
Ridge (MD-SM-1) 38.12 N -76.36 W								10.46
Great Mills (SMC10) 38.26 N -76.49 W								10.16
Delaware								
ICAO Sites								
Dover AFB (KDOV)			28/1955	21	37			7.83

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)			
Georgetown (KGED)	28/0654	971.1	27/2210	36	52			5.60
Wilmington (KILG)	28/0951	976.5	28/1651	31	49			6.94
Marine Observations								
Lewes (LWSD1)	28/0730	968.4	27/2206	41	57	2.98	8.20	
Brandywine Shoal Light (BRND1)	28/0754	968.9	28/1642	53	67	2.70	8.84	
Reedy Point (RDYD1)[h]	28/0924	975.2				1.88	8.03	
Delaware City (DELD1)[h]	28/0942	975.2	28/0154	34	44	3.09	8.82	
New Jersey								
ICAO Sites								
Millville (KMIV)	28/0854	970.4	28/0254	27	43			6.31
Trenton (KTTN)	28/1153	972.2	28/0326	27	45			5.74
Atlantic City (KACY)	28/0936	965.1	28/1812	35	50			5.88
Newark (KEWR)	28/1218	967.5	28/1954	39	53			8.92
Teterboro (KTEB)	28/1246	966.8	28/2007	30	42			8.22
Non-Metar Observations								
Perth Amboy Junction			28/0450		58			
Bayonne (XBYO)			28/0830		45			
Robbins Reef (ROBN4)			28/0800		61			
Marine Observations								
Burlington, Delaware River (BDRN4)[h]	28/1100	972.1	28/0636	33	43	3.42	11.34	
Tacony-Palmyra Bridge (TPBN4)[g,h]	28/1042	973.5				3.44	9.94	
Ship John Shoal (SJSN4)	28/0906	971.9	28/0000	41	50	2.47	9.34	
Cape May (CMAN4)	28/0806	967.1	28/1648	51	65	2.48	8.55	
Atlantic City Marina (ACMN4)			28/0115	30	55			
Atlantic City (ACYN4)	28/0930	960.1				2.15	6.96	
Sandy Hook (SDHN4)	28/1236	962.9	28/2042	40		4.63	9.75	
Public/Other								
Denton 38.84 N -75.92 W								11.68
Hickman 38.83 N -75.72 W								10.50

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)			
Ellendale 38.80 N -75.42 W								10.43
Stockton 40.40 N -74.98 W								10.32
Pennsylvania								
ICAO Sites								
Philadelphia (KPHL)	28/0954	974.6	28/1754	30	45			5.70
Allentown (KABE)	28/1251	978.9	28/0651	29	46			5.01
Pottstown (KPTW)	28/1054	978.1	28/0413	24	38			5.94
Marine Observations								
Newbold (NBLP1)[h]	28/1118	971.1	28/2054	26	38	3.37	11.98	
Philadelphia (PHBP1)[h]	28/1012	973.3	28/0212	20	35	2.77	9.93	
Marcus Hook (MRCP1)[h]	28/1000	974.6				2.60	9.04	
New York								
ICAO Sites								
New York - Kennedy (KJFK)	28/1207	967.8	28/2048	40	51			5.02
New York - LaGuardia (KLGA)	28/1231	966.1	28/0710	45	58			5.37
New York – Central Park (KNYC)	28/1236	965.8	28/0659	28	52			6.87
White Plains (KHPN)	28/1329	969.9	28/2038	32	49			
Islip (KISP)	28/1252	975.3	28/1109	41	54			3.03
Farmingdale (KFRG)	28/1240	972.9	28/1156	39	53			
Albany (KALB)	28/1751	978.4	29/0044	32	47	7.23	11.11	
Poughkeepsie (KPOU)	28/1553	972.2	29/0021	23	37	5.35	7.92	
Plattsburgh (KPBG)	28/2106	986.0	28/1950	36	50			3.73
Non-Metar Observations								
Jones Beach Coast Guard (XJON)			28/0755		56			
Bayville			28/0827		58			
Fishers Island (XFSH)			28/0950		50			
Sayville (AT614)			28/1102		79			
East Moriches (D5220)			28/1020		62			
Marine Observations								

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)			
Bergen Point West Reach (BGNN4)	28/1306	966.1	28/2054	28	40	4.56	10.22	
The Battery (BATN6)	28/1312	964.6				4.36	9.50	
Kings Point (KPTN6)	28/1342	968.2	28/2306	33	43	4.46	12.33	
East Rockaway						4.48	8.92	
Point Lookout						4.42	8.17	
Freeport						4.73	8.15	
Montauk (MTKN6)	28/1636	983.4				2.75	5.38	
Public/Other								
Tuxedo Park 41.20 N -74.21 W								11.48
Harriman 41.30 N -74.14 W								10.45
Harrison 40.74 N -74.15 W								9.14
Yonkers 40.94 N -73.87 W								8.15
Whiteface Mountain								7.55
Connecticut								
ICAO Sites								
Bridgeport (KBDR)	28/1412	975.6	28/0831	40	55			3.50
Groton (KGON)	28/1258	983.1	28/1257	40	50			
New Haven (KHVN)	28/1540	977.7	28/1336	37	58			3.34
Windsor Locks (KBDL)	28/1751	977.1	29/0151	26	44			5.23
Danbury (KDXR)	28/1454	973.2	28/1012	27	41			6.72
Marine Observations								
Bridgeport (BRHC3)	28/1500	975.4	28/1436	37	45	4.44	12.08	
New Haven (NWHC3)	28/1630	977.0	28/1554	35	45	4.65	11.57	
New London (NLNC3)	28/1748	983.5	28/1442	37	47	3.49	6.55	
Rhode Island								
ICAO Sites								
Providence (KPVD)	28/1951	984.4	28/1626	34	56			1.98
Block Island (KBID)	28/1815	989.4	29/0015	31	48			0.75
Westerly (KWST)	28/1753	984.0	28/1435	31	46			0.87
Marine Observations								

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)			
Quonset Point (QPTR1)	28/1818	983.4	28/1642	44	56	2.38	6.88	
Providence (FOXR1)	28/1936	983.2	28/1548	42	58	4.65	8.25	
Conimicut Light (CPTR1)	28/1948	983.1	28/1330	55	72	2.47	7.59	
Newport (NWPR1)	28/1812	984.7	28/1642	39	51	2.31	6.54	
Massachusetts								
ICAO Sites								
Nantucket (KACK)	28/1953	991.7	28/2353	35	55			0.03
Boston (KBOS)	28/2154	983.6	28/1554	38	55			1.68
Chatham (KCQX)	28/2152	991.1	28/1852	24	52			0.06
New Bedford (KEWB)	29/1953	1000.0	28/1453	35	50			0.28
Falmouth (KFMH)	28/2115	991.8	28/2255	36	52			
Hyannis (KHYA)	28/2156	990.3	28/1814	38	57			0.07
Milton (KMQE)	28/1954	984.0	28/1654	37	70			1.99
Marine Observations								
Nantucket Island (NTKM3)	28/2024	991.1	28/1748	26	42	1.28	4.53	
Menemsha Harbor, Martha's Vineyard (8448725)						2.43	5.29	
Woods Hole (BZBM3)	28/2048	988.9				2.87	4.61	
Chatham (8447435)						1.59	7.45	
Fall River (FRVM3)	28/1948	985.4				1.95	7.30	
Boston (BHBM3)	28/2112	983.3				1.72	11.95	
Public/Other								
Conway 42.51 N -72.68 W								9.92
Ashfield 42.52 N -72.79 W								9.75
Shelburne Falls 42.60 N -72.74 W								8.50
Vermont								
ICAO Sites								
Springfield (KVSF)	28/2054	979.5	28/2309		35			5.66
St. Johnsbury (K1V4)	28/2054	980.7						4.60
Montpelier (KMPV)	28/1951	983.6						4.46

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)			
Morrisville (KMVL)	28/2154	982.9						3.59
Rutland (KRUT)	28/1955	980.2						3.50
Burlington (KBTV)	28/2049	983.3	29/0038		43			3.38
Public/Other								
South Lincoln								8.15
Alpine Village								7.87
Ludlow								7.86
Jeffersonville								7.76
Groton								7.72
Cavendish								7.60
Jay								7.50
East Orange								7.40
Woodstock								7.34
Randolph Center								7.28
New Hampshire								
ICAO Sites								
Nashua	28/2051	981.8	28/1353	28	45			3.04
Manchester (KMHT)	28/2053	981.0	28/1651	27	44			3.31
Concord (KCON)	28/2251	981.0	28/1551	21	45			
Mt. Washington (KMWN) (elevation 6266 ft)			29/0655	86	97			
Marine Observations								
Fort Point (8423898)						0.55	10.94	
Maine								
ICAO Sites								
Augusta (KAUG)	29/0253	985.3	28/1934	32	49			
Bar Harbor (KBHB)	29/0255	985.1	29/2115	32	46			
Bangor (KBGR)	29/0253	985.4	28/2053	28	42			
Marine Observations								
Wells (WELM1)	29/0042	983.5	28/1736	29	38	0.80	11.22	
Portland (CASM1)	29/0224	983.4				1.08	11.96	
Bar Harbor (ATGM1)	29/0442	989.8	29/1218	20	37	1.25	13.65	

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)			
Eastport (PSBM1)	29/0724	991.9	29/0036	36	47	1.09	22.02	
Buoys								
41043 Southwest Atlantic	22/0750	1010.6	22/1336	37	45			
41046 Eastern Bahamas	24/0650	1010.3	23/0850	35	39			
41047 Southwest Atlantic	25/0850	1011.9	25/1846	35	39			
41009 E of Cape Canaveral	26/0720	1000.1	26/0350	31				
41010 Cape Canaveral	26/0720	982.2	26/0620	49				
41012 St. Augustine	26/1050	1001.4	26/1430	32	41			
41008 Grays Reef	27/2150	1001.7	26/1640	31	43			
41004 Charleston	26/2350	991.6	26/2310	45	56			
41013 Frying Pan Shoals	27/0650	976.1	26/2210	47	60			
41036 Onslow Bay	27/1020	956.7	27/1620	49	64			
41001 Cape Hatteras	27/1850	997.3	27/1850	38	52			
44014 Virginia Beach	28/0050	969.5	27/2310	44	56			
44009 Cape May	28/0550	967.8	27/2140	42	54			
44065 Entrance to NY Harbor	19/1250	968.3	28/1220	47	52			
44008 Nantucket	28/1950	996.0	28/1750	36	47			
44018 Cape Cod	28/2050	994.1	29/0150	31	39			
44020 Nantucket Sound	28/2050	989.2	28/2350	41	50			
44013 Boston	28/2050	984.0	28/1550	36	49			
44005 Gulf of Maine			28//225	37				
44007 Gulf of Maine	29/0150	983.2	28/2250	32	45			

* Observation adjusted to 10 m by Dr. John Schroeder (program director)and colleagues from Texas Tech University Hurricane Research Team.
[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 period is 8 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is referenced above Mean Lower Low Water (MLLW). Bold numbers indicate that the maximum recorded water level exceeded historical maximum values.
[e] Anemometer height 5 m.
[f] Wind averaging period 10 min.
[g] Sensor reached physical limit on measurements and did not record a maximum value.
[h] Maximum storm tide/storm surge likely includes effects from freshwater runoff.

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Irene, 21 -28 August 2011. Mean errors for the 5-yr period 2006-10 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**23.8**	**38.0**	**53.0**	**68.4**	**101.2**	**132.2**	237.1
OCD5	38.1	65.5	92.1	112.7	174.10	222.1	245.5
Forecasts	30	28	26	24	20	16	12
OFCL (2006-10)	31.0	50.6	69.9	89.5	133.2	174.2	214.8
OCD5 (2006-10)	47.7	98.3	156.4	218.1	323.3	402.2	476.1

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Irene. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	22.1	35.9	51.8	67.1	95.5	127.7	235.1
OCD5	34.1	58.8	87.2	105.1	165.2	223.0	247.1
GFSI	**21.9**	**32.8**	**43.4**	**52.6**	**71.7**	**89.7**	**162.3**
GHMI	29.0	42.9	66.3	96.2	162.6	231.1	400.5
HWFI	23.2	**34.5**	**39.9**	**50.1**	**78.7**	**125.7**	**231.9**
GFNI	27.9	45.2	67.5	82.4	99.6	**84.8**	**93.7**
NGPI	29.2	46.0	63.0	79.1	110.0	**123.2**	**136.3**
EGRI	27.5	53.4	81.8	117.0	186.0	269.4	422.0
EMXI	**21.2**	**34.4**	**46.7**	**63.3**	**92.1**	**101.5**	**170.8**
AEMI	**21.5**	38.2	53.4	75.1	117.2	135.9	**194.8**
FSSE	23.5	41.1	54.5	71.8	114.6	159.0	259.1
TCON	22.5	**35.2**	**50.1**	**69.1**	105.5	144.3	239.0
TCCN	22.7	37.2	52.8	74.5	114.0	177.9	307.6
TVCA	22.8	36.1	**49.9**	69.3	105.5	139.0	**233.1**
TVCC	22.4	37.3	52.2	72.2	107.8	154.0	253.7
GUNA	23.2	37.7	55.6	76.4	116.8	152.4	244.0
LBAR	25.9	41.9	64.0	88.1	140.1	155.7	**187.4**
BAMD	25.5	39.8	**49.7**	**55.7**	**81.0**	**108.1**	**211.7**
BAMM	33.5	54.9	84.3	115.2	157.9	163.5	**198.1**
BAMS	56.5	103.9	155.5	196.4	238.1	200.8	**168.3**
Forecasts	26	24	23	21	18	15	11

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Irene, 21-28 August 2011. Mean errors for the 5-yr period 2006-10 are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	10.2	13.9	18.3	21.5	28.5	25.9	22.9
OCD5	9.1	11.9	13.4	15.4	17.8	17.6	12.7
Forecasts	30	28	26	24	20	16	12
OFCL (2006-10)	7.2	11.0	13.2	15.1	17.2	17.9	18.7
OCD5 (2006-10)	8.5	12.3	15.4	17.8	20.2	21.9	21.7

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Irene, 21-28 August 2011. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	10.2	13.9	18.3	21.5	28.5	25.9	22.9
OCD5	**9.1**	**11.9**	**13.4**	**15.4**	**17.8**	**17.6**	**12.7**
GHMI	11.3	15.6	22.0	23.6	29.4	**24.9**	23.6
HWFI	**10.0**	14.0	**15.1**	**19.6**	**21.2**	27.2	27.1
FSSE	10.5	15.0	**16.7**	**17.6**	**22.7**	**20.6**	23.1
DSHP	10.6	14.5	**16.3**	**19.0**	**24.3**	28.1	**22.8**
LGEM	**9.7**	**12.9**	**15.7**	**18.3**	**20.3**	**22.5**	**20.8**
ICON	**10.1**	**13.4**	**15.8**	**18.6**	**22.5**	**22.1**	**12.6**
IVCN	10.3	**13.5**	**16.4**	**18.8**	**23.1**	**22.2**	**12.2**
Forecasts	30	28	26	24	20	16	12

Table 6. Watch and warning summary for Hurricane Irene, 21- 28 August 2011.

Date/Time (UTC)	Action	Location
20 / 2300	Tropical Storm Warning issued	British Virgin Islands, Saint Kitts, Nevis, Antigua, Anguilla, Montserrat, Barbuda
20 / 2300	Tropical Storm Warning issued	Saba, St. Maartin, St. Eustatius
20 / 2300	Tropical Storm Warning issued	Dominica
21 / 0300	Tropical Storm Watch issued	South coast of Dominican Republic from Haiti border to Cabo Engano
21 / 0900	Tropical Storm Watch changed to Hurricane Warning	South coast of Dominican Republic/Haiti border to Cabo Engano
21 / 0900	Tropical Storm Watch issued	Haiti
21 / 0900	Tropical Storm Warning issued	St. Martin and St. Barthelemy
21 / 0900	Tropical Storm Warning issued	North coast of the DR/Haiti N border to Cabo Engano
21 / 0900	Hurricane Watch issued	Puerto Rico
21 / 1200	Tropical Storm Warning discontinued	Dominica
21 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Haiti
21 / 1500	Tropical Storm Warning changed to Hurricane Watch	U.S. Virgin Islands
21 / 1500	Tropical Storm Warning changed to Hurricane Warning	Puerto Rico
21 / 1500	Tropical Storm Watch issued	Southeastern Bahamas and Turks and Caicos
21 / 1500	Tropical Storm Warning modified	North coast Dominican Republic /Haiti border to Cabo Frances Viejo
21 / 1500	Tropical Storm Warning issued	U.S Virgin Islands
21 / 1500	Hurricane Watch discontinued	Puerto Rico
21 / 1500	Hurricane Warning modified to	South coast of Dominican Republic /Haiti south border to Cabo Francis Viejo
21 / 1800	Tropical Storm Warning discontinued	British Virgin Islands, Saint Kitts, Nevis,

		Antigua, Anguilla, Montserrat, Barbuda
21 / 1800	Tropical Storm Warning issued	British Virgin Islands
21 / 2100	Tropical Storm Warning discontinued	Saba, St. Maartin, and St. Eustatius
21 / 2100	Tropical Storm Warning discontinued	Dominican Republic /Haiti N border to Cabo Francis Viejo
21 / 2100	Hurricane Warning discontinued	Dominican Republic/Haiti S border to Cabo Francis Viejo
21 / 2100	Hurricane Warning issued	Dominican Republic
22 / 0000	Tropical Storm Watch changed to Tropical Storm Warning	Southeastern Bahamas, Turk and Caicos
22 / 0000	Tropical Storm Watch issued	Central Bahamas
22 / 0300	Tropical Storm Watch changed to Hurricane Watch	Central Bahamas
22 / 0300	Tropical Storm Warning discontinued	St. Martin and St. Barthelemy
22 / 0700	Tropical Storm Warning issued	Dominican Republic /Haiti south border to Cabo Engano
22 / 0700	Hurricane Warning discontinued	Dominican Republic
22 / 0700	Hurricane Warning issued	Dominican Republic/Haiti north border to Cabo Engano
22 / 0900	Hurricane Watch changed to Tropical Storm Warning	U.S. Virgin Islands
22 / 0900	Hurricane Watch issued	Le Mole St. Nicholas to Dominican Republic/Haiti N border
22 / 1300	Hurricane Warning changed to Tropical Storm Warning	Puerto Rico
22 / 1500	Tropical Storm Warning changed to Hurricane Warning	Southeastern Bahamas, Turks and Caicos
22 / 1500	Tropical Storm Warning discontinued	U.S. Virgin Islands
22 / 1500	Tropical Storm Warning discontinued	British Virgin Islands
22 / 1800	Tropical Storm Warning discontinued	Puerto Rico
22 / 1800	Tropical Storm Warning modified to	Santo Domingo to Cabo Engano

22 / 2100	Hurricane Watch discontinued	Central Bahamas
22 / 2100	Hurricane Watch issued	Northwestern Bahamas
22 / 2100	Hurricane Warning discontinued	Southeastern Bahamas, Turks and Caicos
22 / 2100	Hurricane Warning issued	Central Bahamas and Southeastern Bahamas, Turks and Caicos
23 / 1500	Hurricane Warning changed to Tropical Storm Warning	Dominican Republic/Haiti N border to Cabo Engano
23 / 1500	Tropical Storm Warning modified to	Dominican Republic/Haiti north border to Cabo Engano
23 / 1500	Tropical Storm Warning discontinued	Haiti
23 / 1500	Tropical Storm Warning issued	Le Mole St. Nicholas to Dominican Republic/Haiti north border
23 / 1500	Hurricane Watch discontinued	Northwestern Bahamas
23 / 1500	Hurricane Warning discontinued	Central Bahamas and Southeastern Bahamas, Turk and Caicos
23 / 1500	Hurricane Warning issued	Northwestern, Central and Southeastern Bahamas, Turks and Caicos
23 / 1800	Tropical Storm Warning modified to	Le Mole St. Nicholas to Dominican Republic/Haiti north border
23 / 2100	Hurricane Watch changed to Tropical Storm Warning	Le Mole St. Nicholas to Dominican Republic/Haiti north border
23 / 2100	Tropical Storm Warning modified to	Le Mole St. Nicholas to Dominican Republic/Haiti north border
24 / 0900	Tropical Storm Warning discontinued	All
24 / 1200	Tropical Storm Warning issued	Turks and Caicos
24 / 1200	Hurricane Warning discontinued	Northwestern, Central and Southeastern Bahamas, Turks and Caicos
24 / 1200	Hurricane Warning issued	Northwestern, Central and Southeastern Bahamas
25 / 0000	Tropical Storm Warning discontinued	All
25 / 0900	Tropical Storm Warning issued	Edisto Beach to Surf City

25 / 0900	Hurricane Watch issued	Surf City to North Carolina/Virginia border
25 / 1200	Hurricane Warning discontinued	Northwestern, Central and Southeastern Bahamas
25 / 1200	Hurricane Warning issued	Northwestern and Central Bahamas
25 / 2100	Tropical Storm Warning modified to	Edisto Beach to Little River Inlet
25 / 2100	Hurricane Watch modified to	North Carolina /Virginia border to Sandy Hook
25 / 2100	Hurricane Warning discontinued	Northwestern and Central Bahamas
25 / 2100	Hurricane Warning issued	Northwestern Bahamas
25 / 2100	Hurricane Warning issued	Little River Inlet to North Carolina/Virginia border
26 / 0300	Hurricane Warning discontinued	Northwestern Bahamas
26 / 0300	Hurricane Warning issued	Grand Bahama to Abaco Island
26 / 0900	Hurricane Watch modified to	Sandy Hook to Merrimack River
26 / 0900	Hurricane Warning modified to	Little River Inlet to Sandy Hook
26 / 1500	Hurricane Warning discontinued	Grand Bahama to Abaco Island
26 / 2100	Tropical Storm Watch issued	Merrimack River to Eastport
26 / 2100	Tropical Storm Warning issued	Sagamore Beach to Merrimack River
26 / 2100	Hurricane Watch discontinued	All
26 / 2100	Hurricane Warning modified to	Little River Inlet to Sagamore Beach
27 / 0900	Tropical Storm Warning modified to	South Santee River to Little River Inlet
27 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Merrimack River to Eastport
27 / 1500	Tropical Storm Warning discontinued	South Santee River to Little River Inlet
27 / 1500	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
27 / 1800	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
27 / 1800	Tropical Storm Warning issued	U.S./Canada border to Porters Lake
27 / 2100	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River

27 / 2100	Hurricane Warning modified to	Cape Fear to Sagamore Beach
27 / 2300	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 0100	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 0100	Hurricane Warning modified to	Cape Lookout to Sagamore Beach
28 / 0300	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 0600	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 0900	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 0900	Tropical Storm Warning issued	Okracoke Inlet to Chincoteague
28 / 0900	Hurricane Warning modified to	Chincoteague to Sagamore Beach
28 / 1200	Tropical Storm Warning modified to	Cape Charles Light to Chincoteague
28 / 1200	Tropical Storm Warning modified to	Sagamore Beach to Merrimack River
28 / 1500	Tropical Storm Warning modified to	Chincoteague to Eastport
28 / 1500	Tropical Storm Warning discontinued	Sagamore Beach to Merrimack River
28 / 1500	Tropical Storm Warning modified to	Chincoteague to Eastport
28 / 1500	Hurricane Warning discontinued	All
28 / 1800	Tropical Storm Warning modified to	Cape Henlopen to Eastport
29 / 0000	Tropical Storm Warning modified to	Manasqan to Eastport
29 / 0300	Tropical Storm Warning discontinued	Manasqan to Eastport

Table 7. Causes of direct deaths associated with Hurricane Irene, 21-28 August, 2011.

Location	Storm Surge/ Rip currents/ waves	Fresh water/rainfall	Wind/falling trees	Tornadoes	Unknown causes
Dominican Republic		3	1		1
Haiti		3			
USA					
Puerto Rico		1			
Florida					
Volusia Co.	1				
North Carolina					
Pitt Co.			2		
Sampson Co.			1		
Nash Co.			1		
Virginia			1		
Chesterfield Co.			1		
City of Newport News					
City of Virginia Beach	1		1		
Brunswick Co.			1		
City of Hopewell					
Maryland			1		
Queen Anne's Co.					
Delaware					
New Castle Co.		2			
New York					
Greene Co.		2			
Montgomery Co.		1			
Delaware Co.		1			
Albany Co.		1			
Suffolk Co.	1				

Westchester Co.		1			
Bronx Co.	1				
Clinton Co.		2			
New Jersey					
Mercer Co.		2			
Salem Co.		1			
Hudson Co.		1			
Morris Co.		1			
Ocean Co.	2				
Pennsylvania.					
Dauphin Co.			1		
Luzerne Co.					
Montgomery Co.		1	1		
Monroe Co.					
Connecticut					
Hartford Co.		1			
Vermont					
Rutland Co.		1			
Windham Co.		1			
Windsor Co.		1			
New Hampshire			1		
Merrimack Co.			1		
Carroll Co.			1		

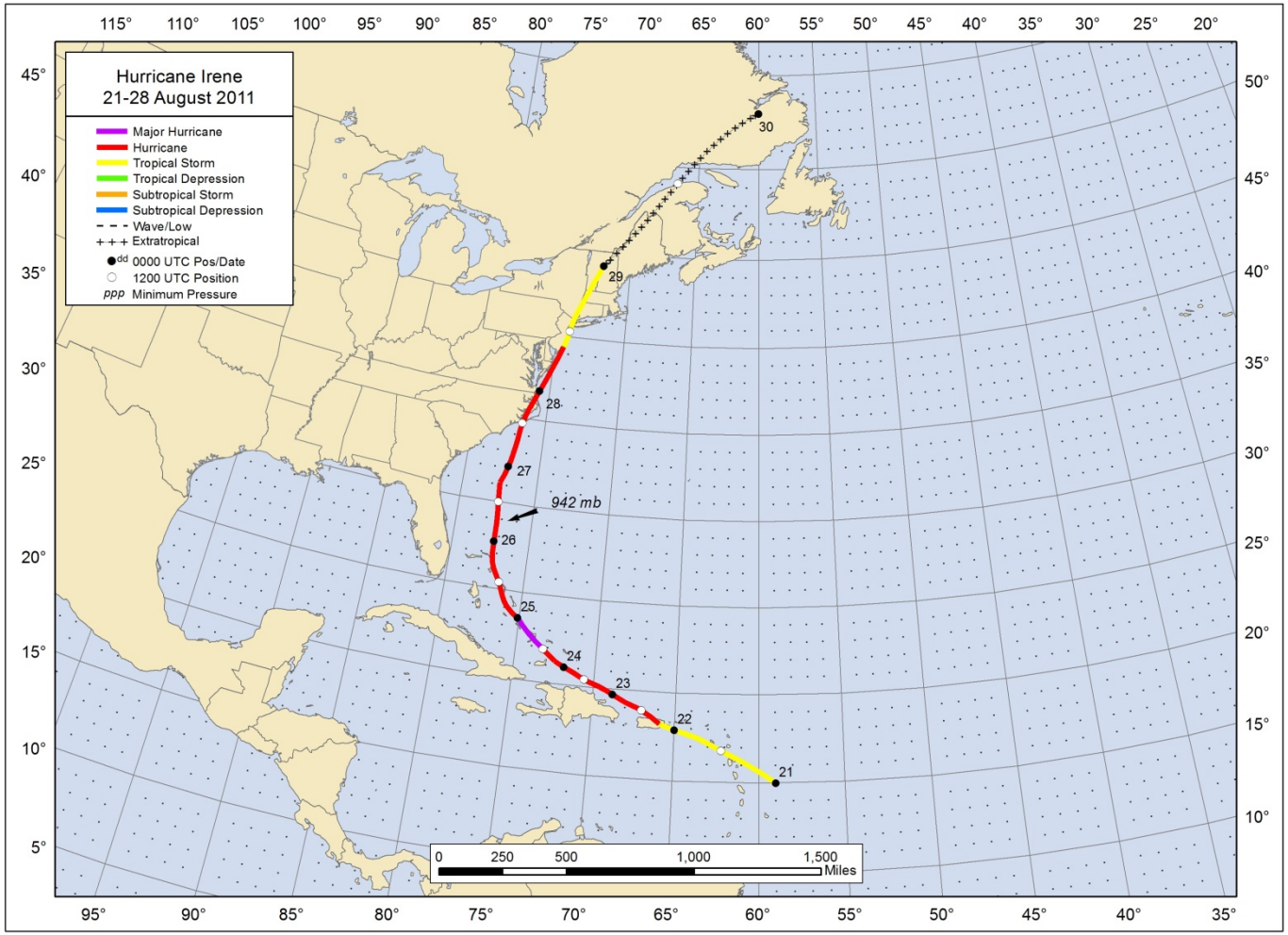


Figure 1. Best track positions for Hurricane Irene, 21 -28 August 2011. Track during the extratropical stage is based on analyses from the NOAA Hydrometeorological Prediction Center.

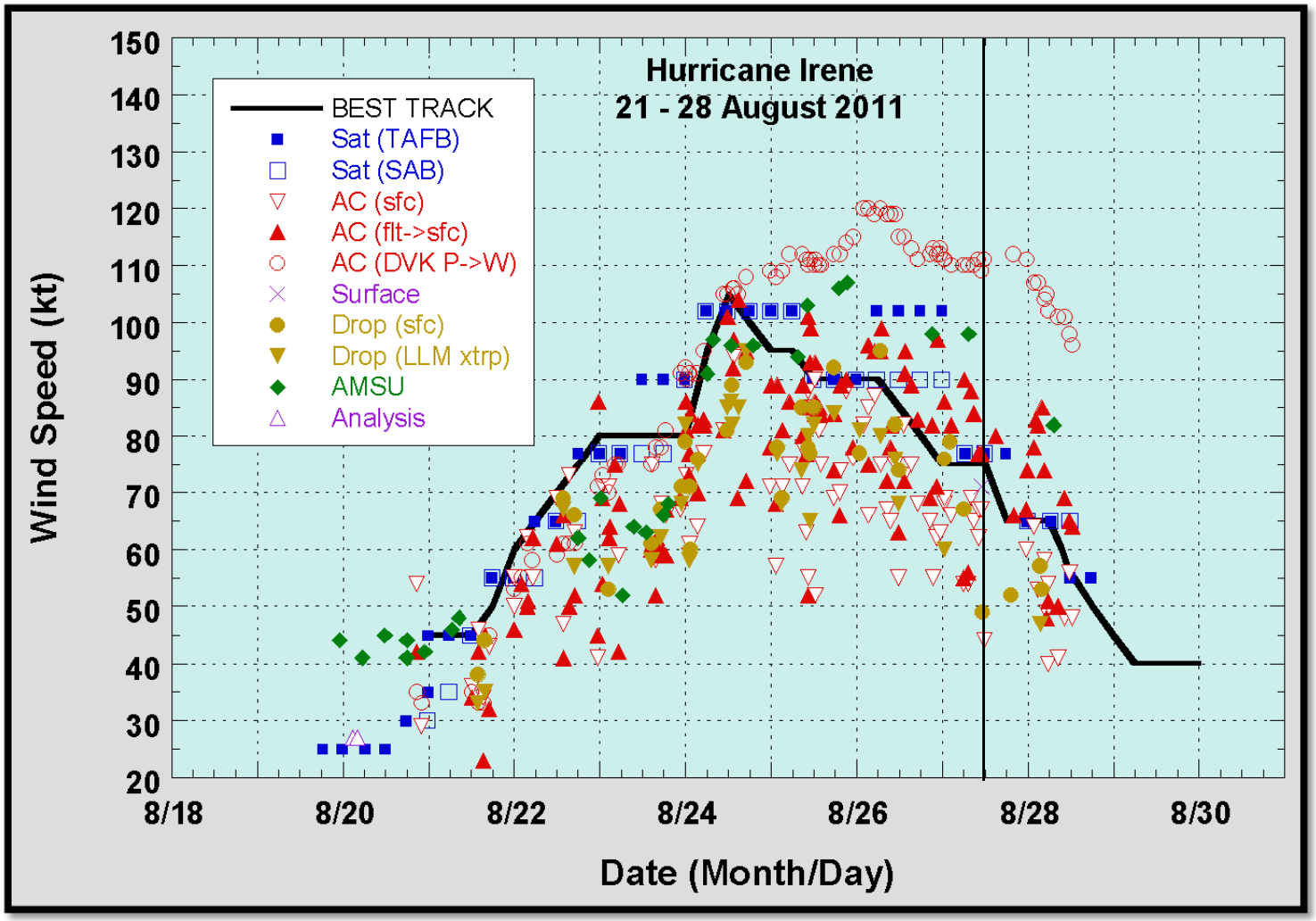


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Irene, 21-28 August 2011. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde 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). Dashed vertical lines correspond to 0000 UTC. The solid vertical line corresponds to the first U.S. east coast landfall near Cape Lookout, North Carolina.

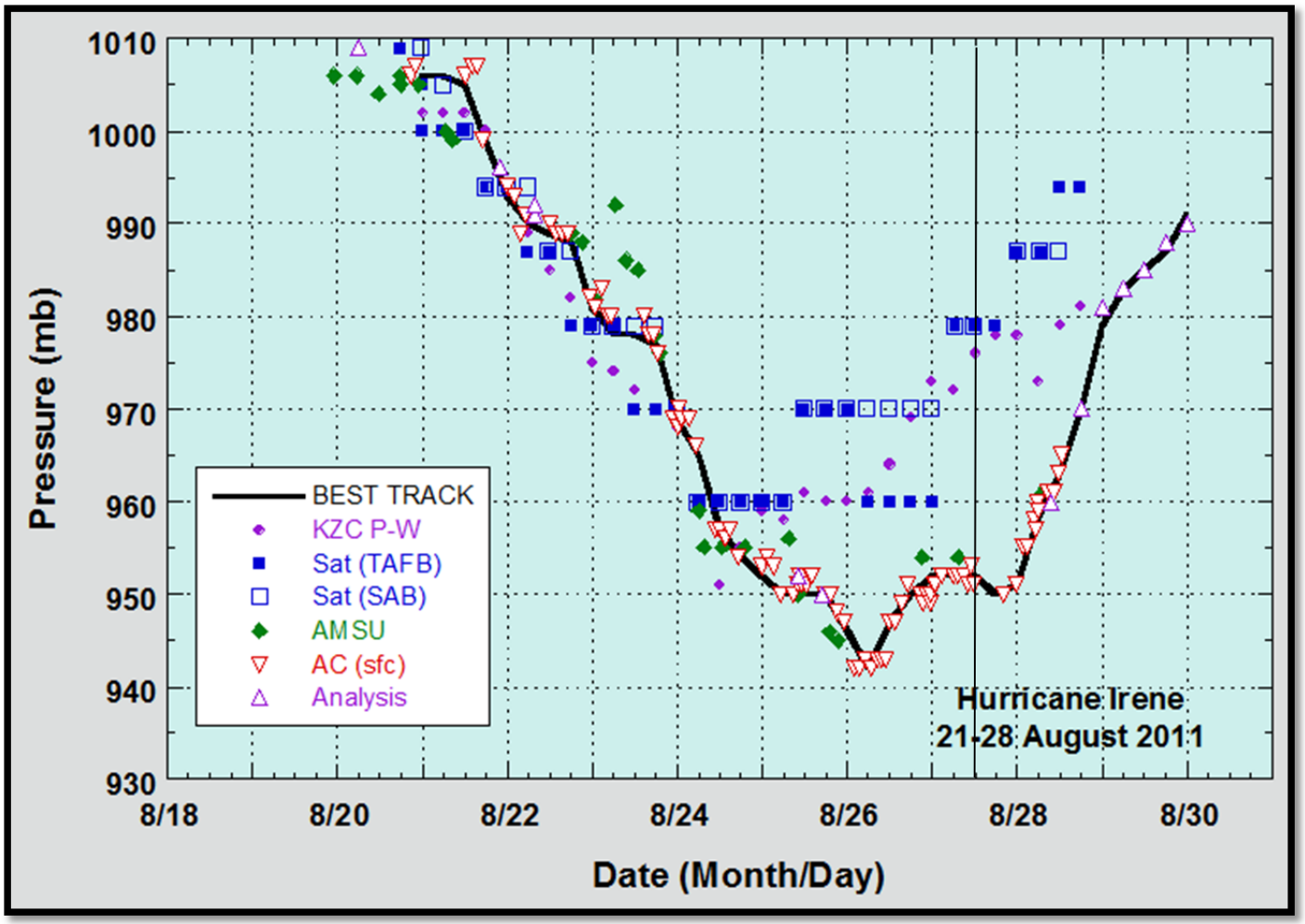


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Irene, 21-28 August 2011. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC. The solid vertical line corresponds to landfall near Cape Lookout, North Carolina.

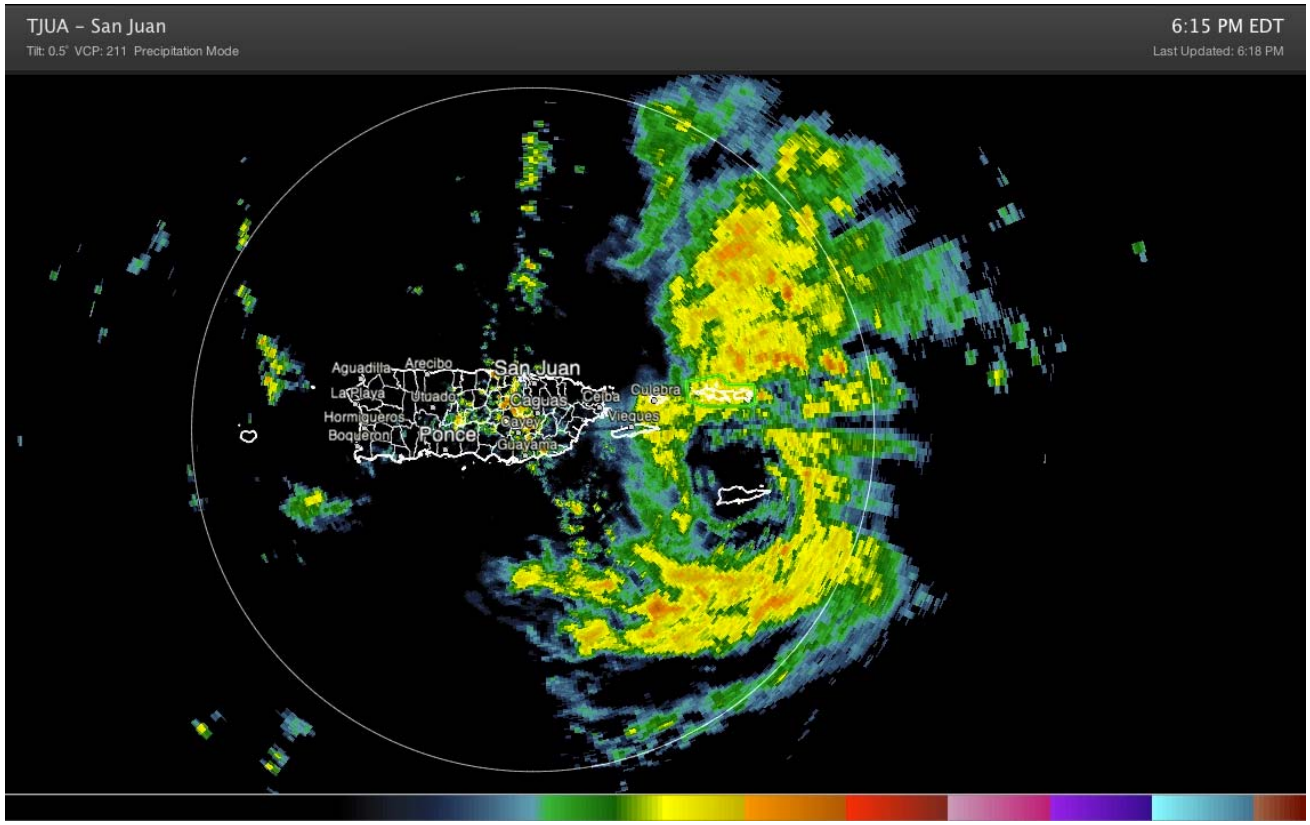
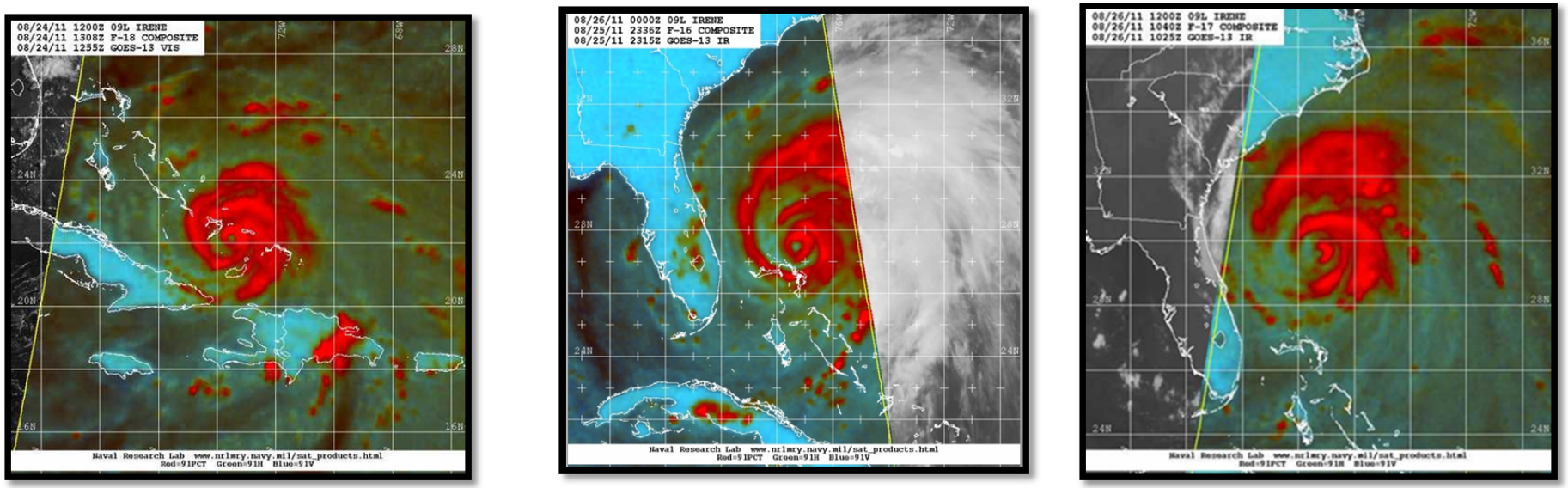


Figure. 4 San Juan Puerto Rico doppler radar image showing the center of Irene moving over St Croix around 2300 UTC 22 August 2011.



(a) **(b)** **(c)**

Figure 5. SSMI/S 91 GHz color composite images at (a) 1308 UTC 24 August 2011, near the time of peak intensity (b) 2536 UTC 25 August and (c) 1040 UTC 26 August 2011, near the time of lowest pressure. Images courtesy of the Naval Research Laboratory in Monterey, California.

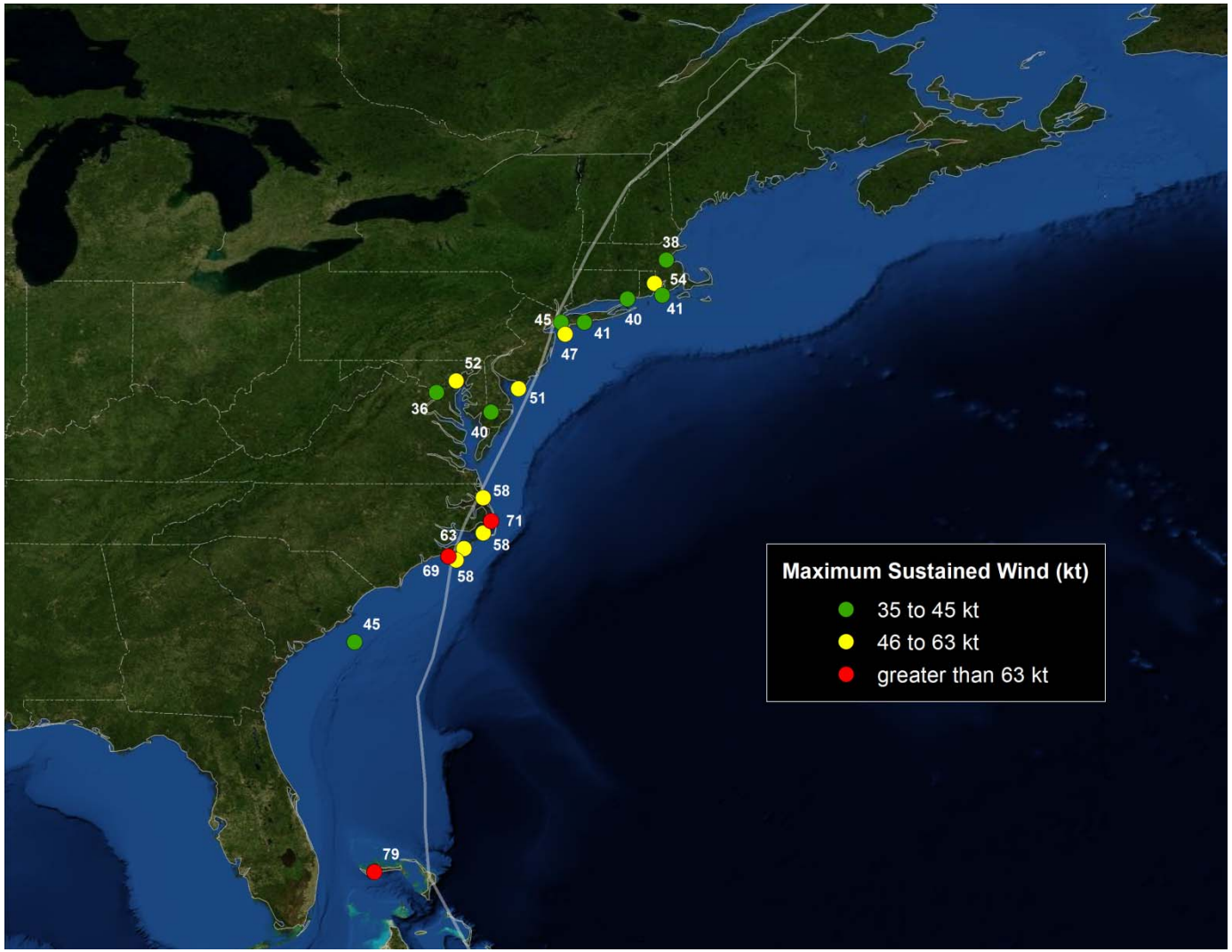


Figure. 6. Selected sustained wind coastal observations in knots associated with Hurricane Irene.

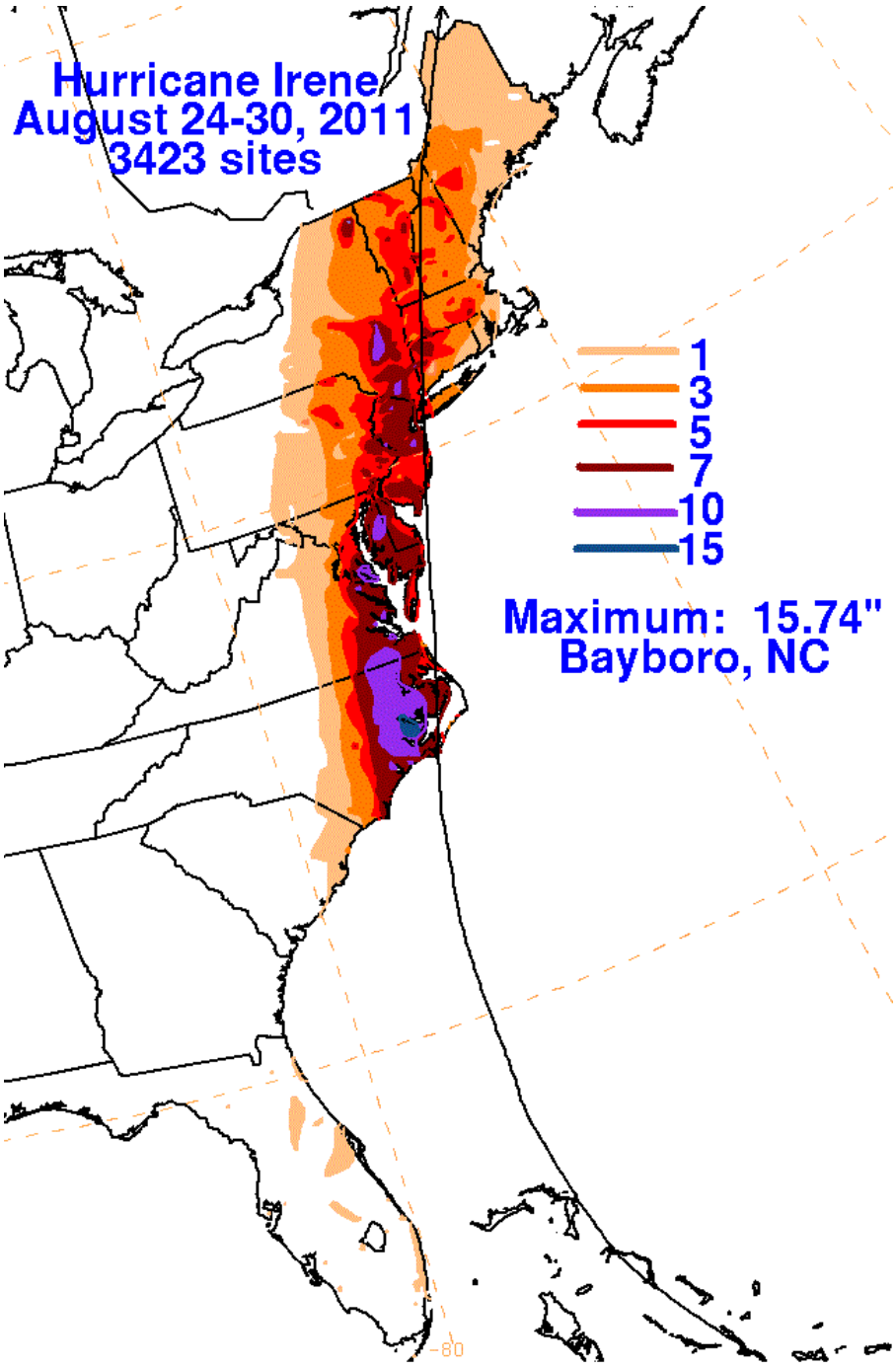


Figure 7. Rainfall totals associated with Hurricane Irene. This map was produced by the NOAA Hydrometeorological Prediction Center.

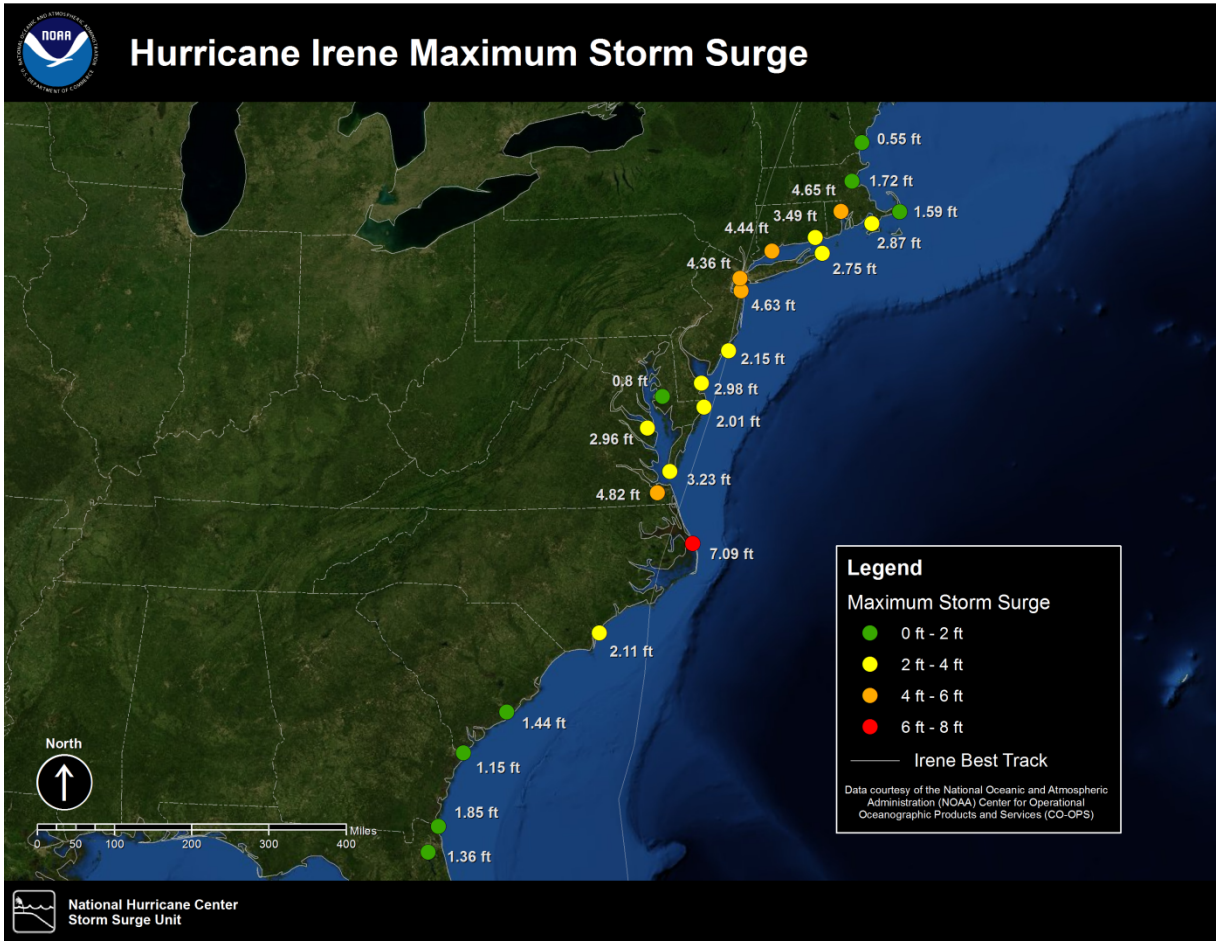


Figure 8. Selected storm surge values in feet associated with Hurricane Irene. Map provided by the NHC storm surge unit.

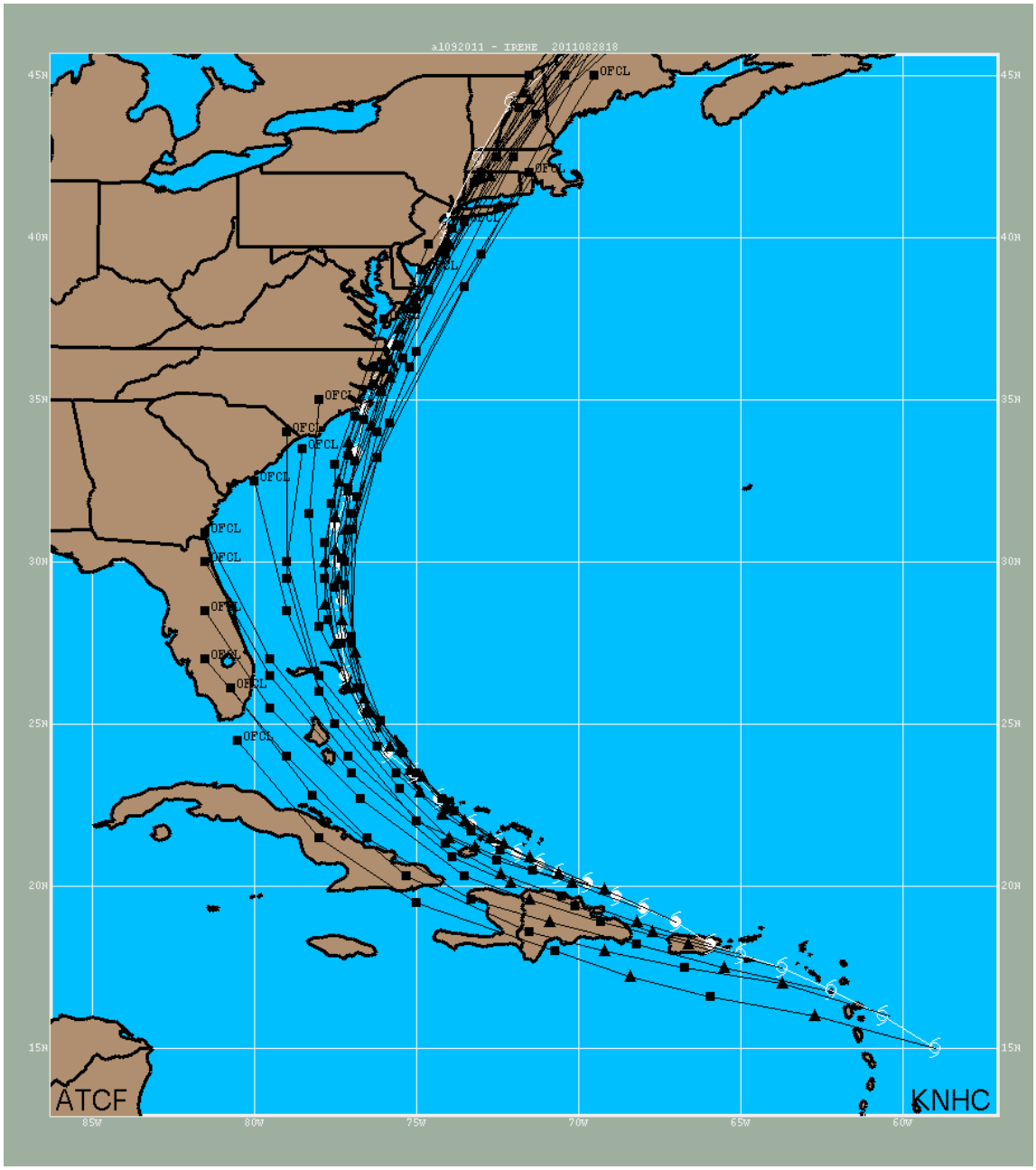


Figure 9. Official NHC track forecasts (black lines) for Irene every 6 h from 0000 UTC 21 August to 1800 UTC 28 August. Observed track is in white.

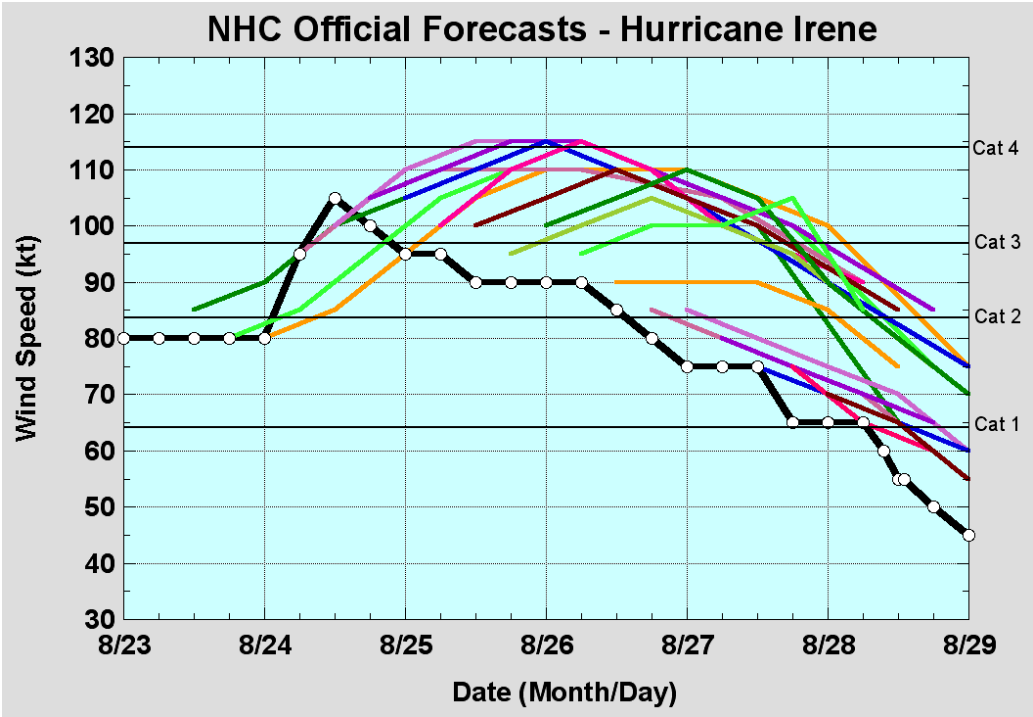


Figure 10. Official NHC intensity forecasts for Irene every 6 h from 1200 UTC 23 August to 0600 UTC 28 August.