

Preliminary Report
Hurricane Bob
16 - 20 August 1991

Hurricane Bob was the first hurricane to strike the northeast United States since Hurricane Gloria in 1985.

a. Synoptic History

Satellite imagery and synoptic analyses indicated that Bob originated from the remnants of a frontal trough. Showers and thunderstorms increased along this frontal trough just south and southeast of Bermuda on 12 August. The area of disturbed weather moved toward the southwest and west during the next few days. Surface analyses at 1200 and 1800 UTC on 15 August indicated that a weak (1015 mb) low had formed within the area of disturbed weather, a couple of hundred nautical miles to the east of the Bahamas. However, animation of high resolution visible satellite imagery during that period revealed only a broad, poorly-defined cyclonic circulation of low clouds near a band of convection with little curvature.

The area of disturbed weather was more organized on satellite imagery the next day. In addition, a closed circulation at a flight level of 1500 ft, and a maximum wind of 32 knots at 0143 UTC were reported by the U.S. Air Force Reserve unit aboard the first reconnaissance flight into the system. Based on these data, it is estimated that the area of disturbed weather became the third tropical depression of the Atlantic hurricane season at 0000 UTC on 16 August, while centered 175 n mi east of Nassau in the Bahamas. Early-light visible satellite pictures on the 16th showed further development, including a more-curved convective band wrapping around the west and south quadrants of a well-defined low-level cloud-system center that was moving west-northwest at about 5 knots. Bob's best track positions are shown in Figs. 1a and 1b, and the best track position, central pressure and maximum one-minute wind speed are listed for every six hours in Table 1.

Both the reconnaissance data near 1800 UTC on 16 August, which included a 51 knot wind at the 1500-ft flight level and a surface pressure of 1005 mb, and satellite intensity estimates from the NESDIS Synoptic Analysis Branch (SAB) and the NHC support upgrading the depression to Tropical Storm Bob at that time. Bob was then centered 120 n mi northeast of Nassau. The storm continued strengthening and began moving more toward the northwest under the influence of the deep layer mean flow.

On 17 August, satellite imagery showed increased convective banding around a central dense overcast. An Air Force reconnaissance plane at 1719 UTC encountered 71 knot winds at the 1500-ft flight level, and a surface pressure of 987 mb was reported. The onboard Air Reconnaissance Weather Officer estimated surface winds at 65 knots. Based on these reports, the best track shows that Bob strengthened to a hurricane at 1800 UTC on the 17th, while centered 205 n mi east of Daytona Beach, Florida. The

hurricane began turning toward the north and then north-northeast at an increasing forward speed. The steering flow was the result of the combined effects of the subtropical high pressure ridge over the Atlantic and a mid- to upper-level trough over the southeastern United States.

Deep convection became more concentrated near the center of the hurricane and a well-defined eye appeared in satellite pictures late on 18 August. Bob continued intensifying and the eye became even more distinct as it passed 25 to 30 n mi east of Cape Hatteras early on the 19th. An Air Force reconnaissance plane at 0412 UTC on 19 August encountered 119 knot winds at the 700 mb flight level. At 0621 UTC a surface pressure of 950 mb was measured. These reports are the basis for showing the maximum surface wind of 100 knots on the best track at 0600 UTC on the 19th while Bob was located about 90 n mi east-southeast of Norfolk, Virginia. Bob was a Category 3 hurricane on the Saffir/Simpson Hurricane Scale at this time and was moving toward the north-northeast near 20 knots.

Bob continued to move toward the north-northeast, steered by the flow between a mid- to upper-level cut-off low near the Great Lakes, and a strong Atlantic subtropical high pressure ridge. In this steering flow, Bob moved parallel to the United States mid-Atlantic coast and headed toward New England on a track similar to the tracks of Hurricanes Carol and Edna in 1954.

Bob weakened while accelerating toward the north-northeast over waters which became significantly cooler off of the mid-Atlantic coast. The eye was partially filled with clouds when it passed just east of Long Island, New York. The west side of a weakened eyewall passed over Montauk Point on the eastern tip of the island. The eye passed over Block Island at 1720 UTC and moved over Newport, Rhode Island near 1800 UTC. Aircraft reconnaissance personnel were unable to report an eye just prior to this landfall, because less than 50 percent of the center was surrounded by an eyewall. By the time of landfall on Rhode Island, Bob was moving toward the north-northeast at 28 knots with maximum sustained winds of a Category 2 hurricane.

Bob crossed Rhode Island and Massachusetts, with the center moving between Boston and Scituate. It then moved over Massachusetts Bay. The hurricane continued to weaken and began losing tropical characteristics as it passed just offshore of the southern coast of Maine and made final landfall as a tropical storm near Rockland, Maine at 0130 UTC on 20 August. Bob turned more toward the northeast and crossed Maine and New Brunswick. Bob exited New Brunswick near Chatham at 1200 UTC on the 20th and became extratropical over the Gulf of St. Lawrence by 1800 UTC. It then crossed northern Newfoundland, and the central North Atlantic along 50-55°N, before moving southeastward and dissipating near the coast of Portugal on 29 August.

b. Meteorological Statistics

Figures 2 and 3 show the curves of minimum central pressure and maximum one-minute wind speed, respectively, versus time, along with the observations on which they are based. Table 2a lists a

selection of the surface observations. Table 2b lists unofficial wind reports made with private wind gages and collected by the Cape Cod Times.

Air Force Reserve Unit aircraft provided most of the reconnaissance on this hurricane from near the time of initial development into a tropical depression east of the Bahamas, until just before final landfall on the coast of Maine. A NOAA plane made a flight into Bob as the hurricane passed the Outer Banks of North Carolina.

Table 2c lists selected hourly observations made by NOAA's National Data Buoy Center (NDBC) platforms near the path of Bob. The NOAA buoys report an 8-minute average sustained wind, and the Coastal-Marine Automated Network (C-MAN) reports give 2-minute average sustained winds. The Diamond Shoals Light C-MAN (35.2°N 75.3°W) reported a minimum pressure of 962.1 mb and maximum sustained winds of 85 knots with gusts to 97 knots at 0200 UTC on 19 August. The Buzzards Bay C-MAN (41.4°N 71.0°W) reported a minimum pressure of 970.8 mb at 1800 UTC on 19 August and maximum sustained winds of 67 knots with gusts to 77 knots at 1700 UTC. Since these were reported hourly observations, they are likely not the extreme values which occurred at the sites. In fact, the continuous wind data from the Diamond Shoals C-MAN received well after the event showed a peak gust of 107 knots.

The wind measurements from Block Island of 91 knots and 87 knots were reported as peak gusts. However, both of these values were at the upper limit of the equipment range and were reportedly maintained (and probably exceeded) for a short period (< 1 min). An observer on Block Island reported the eye overhead at 1720 UTC on 19 August, with the approximate duration of light winds from 30 to 40 minutes.

As the eye moved over Newport, the Navy ship USS VALDEZ, anchored in Narragansett Bay, reported a pressure of 964.0 mb at 1815 UTC on 19 August. A cooperative observer in Adamsville, Rhode Island, just east of the track reported a pressure of 964.1 mb at 1820 UTC. These values are close to the 965 mb pressure reported from an Air Force reconnaissance plane at 1737 UTC just prior to the Newport landfall.

As Bob emerged over the cooler waters of Massachusetts Bay, the maximum sustained surface winds continued to decrease. NOAA buoys 44013 (42.4°N 70.8°W) and 44007 (43.5°N 70.1°W), along with the Mantinicus Rock (43.8°N 68.9°W) and Mt. Desert Rock (44.0°N 68.1°W) C-MAN stations, all reported maximum sustained winds below hurricane force, justifying the downgrading of Bob to a tropical storm before final landfall near Rockland, Maine.

Six confirmed tornadoes were reported in association with Bob, four in North Carolina and two in New York on Long Island. Thirteen additional unconfirmed tornadoes were reported, including nine in the wooded areas on Hatteras Island, two in Rhode Island, and two in Massachusetts.

At the time of publication of this report a post-storm high water mark survey was being conducted by the New England Division of the U.S. Army Corps of Engineers. Initial survey results suggest that the highest storm surge values occurred in Massachusetts and Rhode Island, where wind driven water was funneled into Buzzards and Narragansett Bays. Visual and measured high water marks, which contain both storm surge and astronomical tide heights and in some cases the effects of breaking waves, were also highest there. (Note: storm surge values derived from National Ocean Survey (NOS) tide gages listed in Table 2a have the effects of tide height and wave effects removed.) Specifically, high water marks at the upper end of Buzzards Bay ranged from 8.5 to 15.3 feet. Further south on the east shore at Woods Hole a storm surge of 5.8 feet was calculated from NOS tide gage data. Similarly, on the west shore of Buzzards Bay, a storm surge of 5.8 feet was calculated from tide gage data at the New Bedford hurricane barrier. In Rhode Island, high water marks between 10.2 and 16.5 feet were measured near Sakonnet Point. These values include wave effects because of its exposure on the coast. A storm surge height of 6.5 feet occurred at the Providence hurricane barrier tide gage. The effect of storm surge being "funneled" up Long Island Sound is reflected in the Willets Point NOS tide gage data. This gage, which is located at the west end of the Sound, had a storm surge of 6.7 feet. The surge occurred almost two hours after landfall when the hurricane was abeam of Boston.

Rainfall totals ranged up to nearly eight inches along the path of Bob. The largest totals include 5.30 inches at Cape Hatteras, 7.04 inches at Bridgehampton (on Long Island), 7.00 inches at the Groton Emergency Operations Center in Connecticut, 5.43 inches at Brimfield, Massachusetts, and 7.83 inches at Portland, Maine. Several rainfall amounts between 2 and 5 inches occurred elsewhere over portions of New York and New England.

c. Casualty and Damage Statistics

The total number of deaths associated with Bob is currently set at 17, distributed as follows:

South Carolina	1	New Hampshire	2
North Carolina	1	Maine	3
New York	2	Nova Scotia	2
Connecticut	6	(Canada)	

Three people survived ten days on a life raft after their 38-foot boat sank in high seas off Cape Hatteras.

The American Insurance Association preliminary estimate of insured property damage for the United States is 782 million dollars. This includes 4 million for North Carolina, 75 million for New York, 40 million for Connecticut, 115 million for Rhode Island, 525 million for Massachusetts, 2 million for New Hampshire, and 21 million for Maine. The addition of flood claims, uninsured property damage, and the cost of cleanup increases the total damage estimate from Hurricane Bob to 1.5 billion dollars. Without adjustments for inflation, Bob would rank fifth or sixth on the

list of costliest 20th century United States hurricanes. With adjustments for inflation Bob will rank thirteenth or fourteenth on that list. These damage figures make Bob the most recent of a string of hurricanes that were very costly to the northeast United States. Other prominent, destructive hurricanes there include Gloria in 1985, Agnes in 1972, Donna in 1960, Diane in 1955, Carol in 1954, an unnamed hurricane in 1944, and the New England Hurricane of 1938.

Power was knocked out to an estimated 2.1 million homes and businesses primarily on the Outer Banks of North Carolina, on Long Island, and over portions of New England.

d. Forecast and Warning Critique

Table 3 lists the various watches and warnings along with their time of issuance. About 20 hours lapsed between the time the hurricane warning was issued that included Newport, Rhode Island, and the time the eye passed over Newport.

Table 4 lists the preliminary average official track forecast errors along with the errors of several guidance models. The official errors through 48 hours were considerably less than the previous ten-year averages, and the official error at 72 hours was about the same as the previous ten-year average. The larger errors at 72 hours reflect two "slow" forecasts during the tropical storm stage. The overall track forecasting performance is exceptional for a rapidly accelerating tropical cyclone. It is noted that the BAMD and the NHC90 had comparable or lower average forecast errors than the official forecast for all time periods. The QLM was substantially worse than the official forecasts at 36 hours, comparable at 48 hours, and substantially better at 72 hours for a very limited homogenous sample (not shown).

Although intensification was officially forecast after Bob became a tropical storm, the degree of intensification to a category 3 hurricane was not adequately forecast. This is yet another example to users of National Hurricane Center products, demonstrating the limitations in tropical cyclone intensity forecasting.

Evacuations were confined to the Outer Banks of North Carolina and to the New England area. News reports indicated several thousand people did not evacuate low-lying areas on the Outer Banks. If the eye had moved 30 to 40 n mi west of the actual track in the Cape Hatteras area, perhaps many of those people would have been isolated on those islands with limited services available.

Table 5 lists the probabilities of Hurricane Bob passing within 65 miles of listed locations by date and time.

Max Mayfield

Updated August 10, 1992

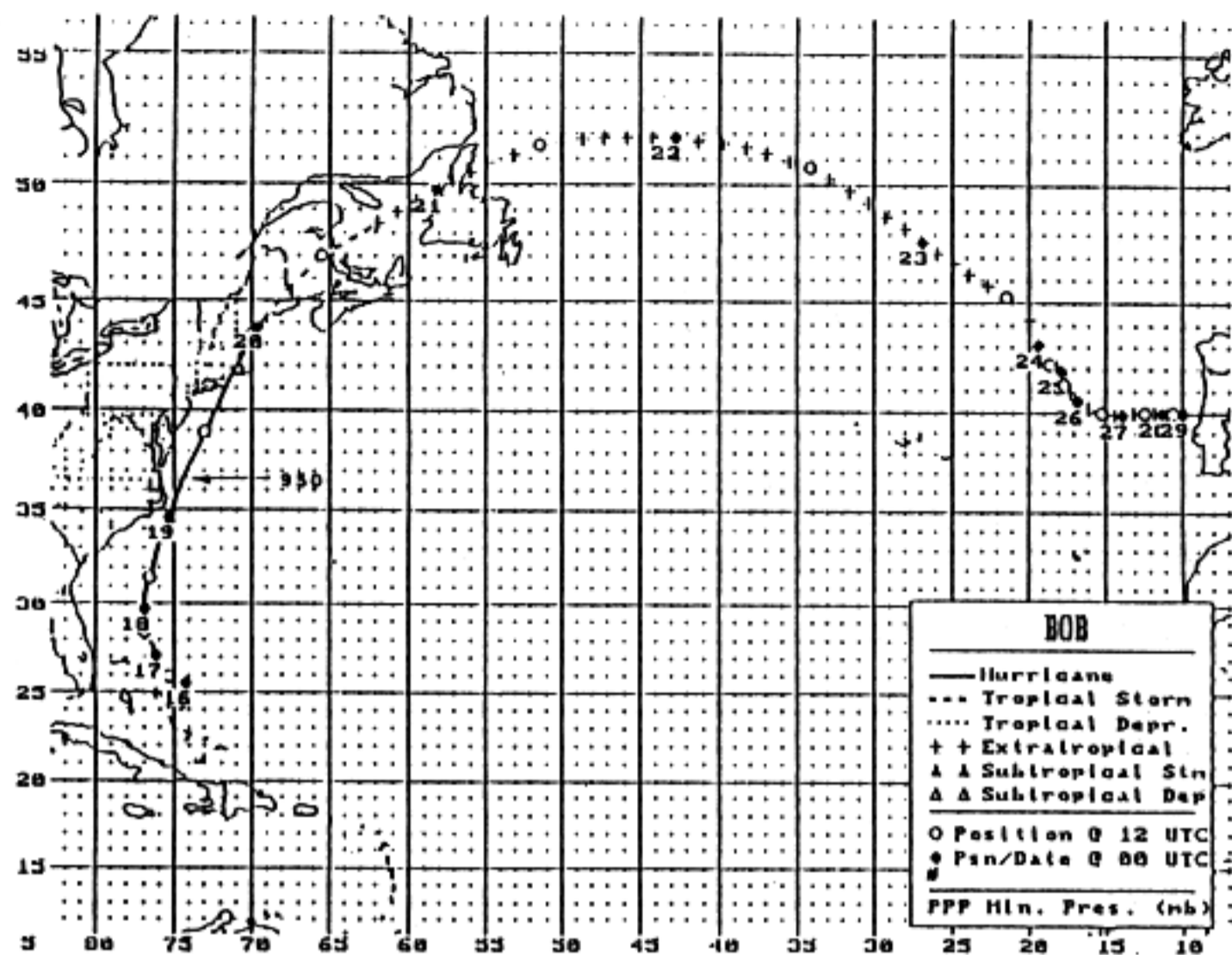


Fig. 1a. Best track positions for Hurricane Bob.

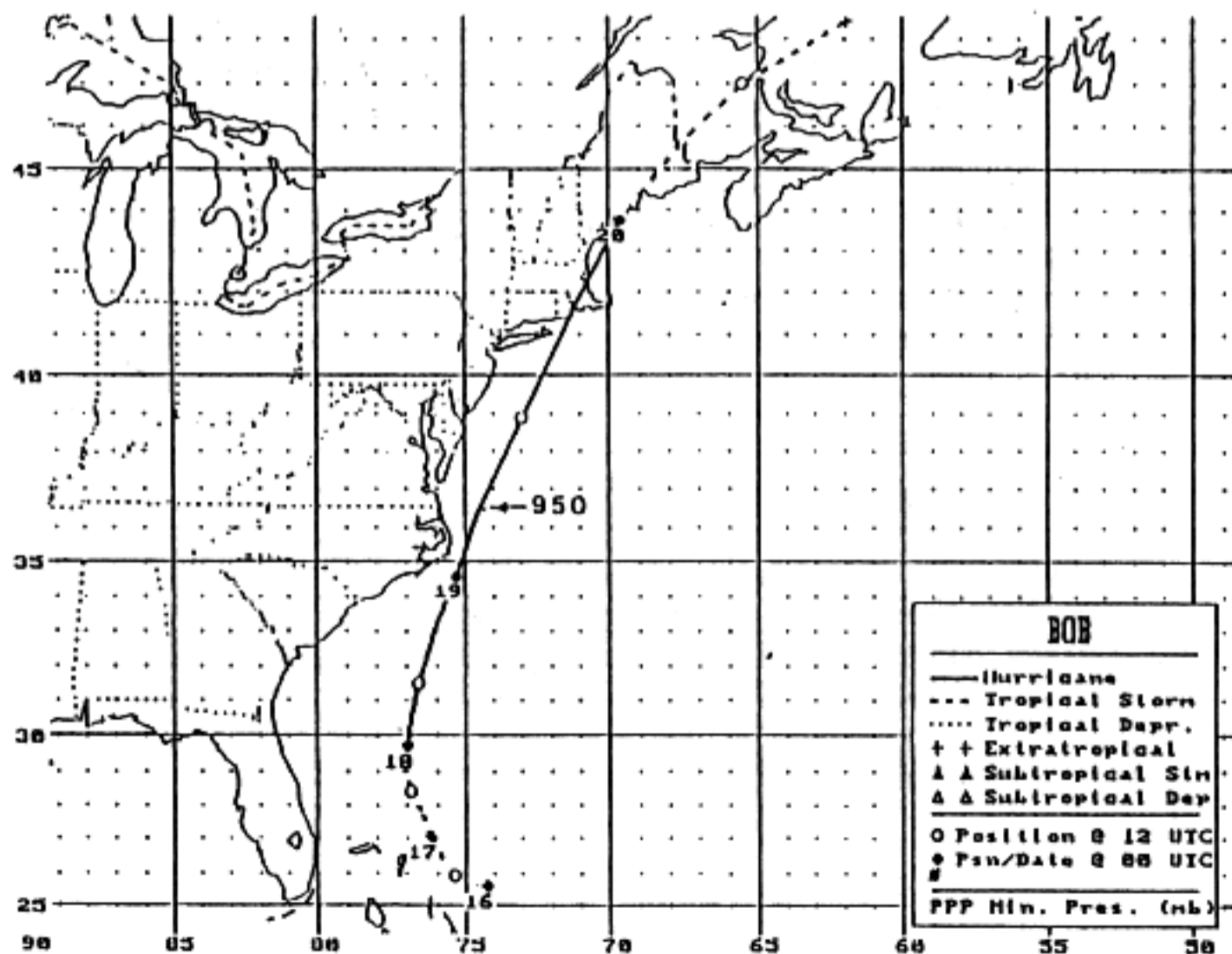


Fig. 1b. Best track positions for Hurricane Bob during the tropical period only, 16-20 August 1991.

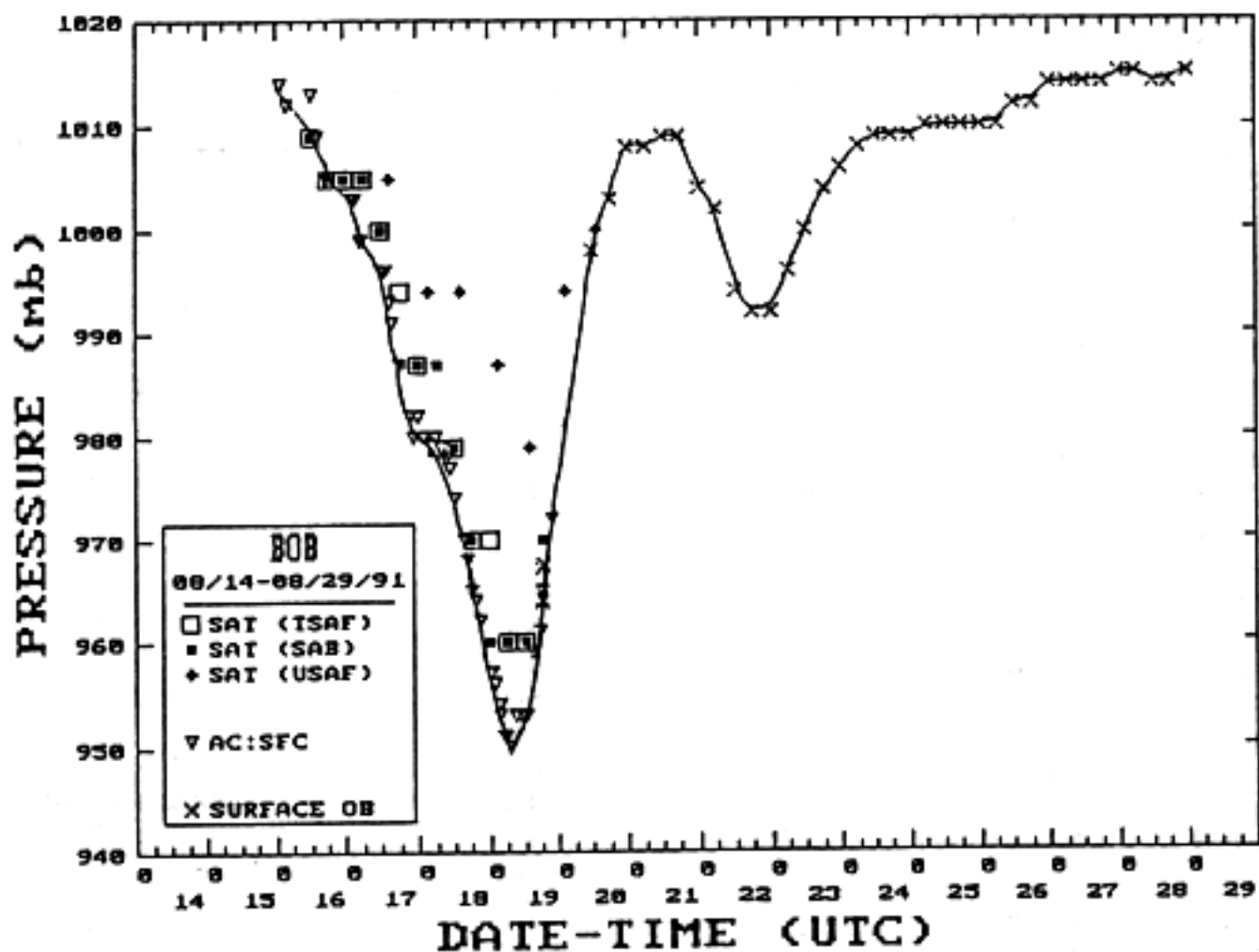


Fig. 2. Best track minimum central pressure curve for Hurricane Bob.

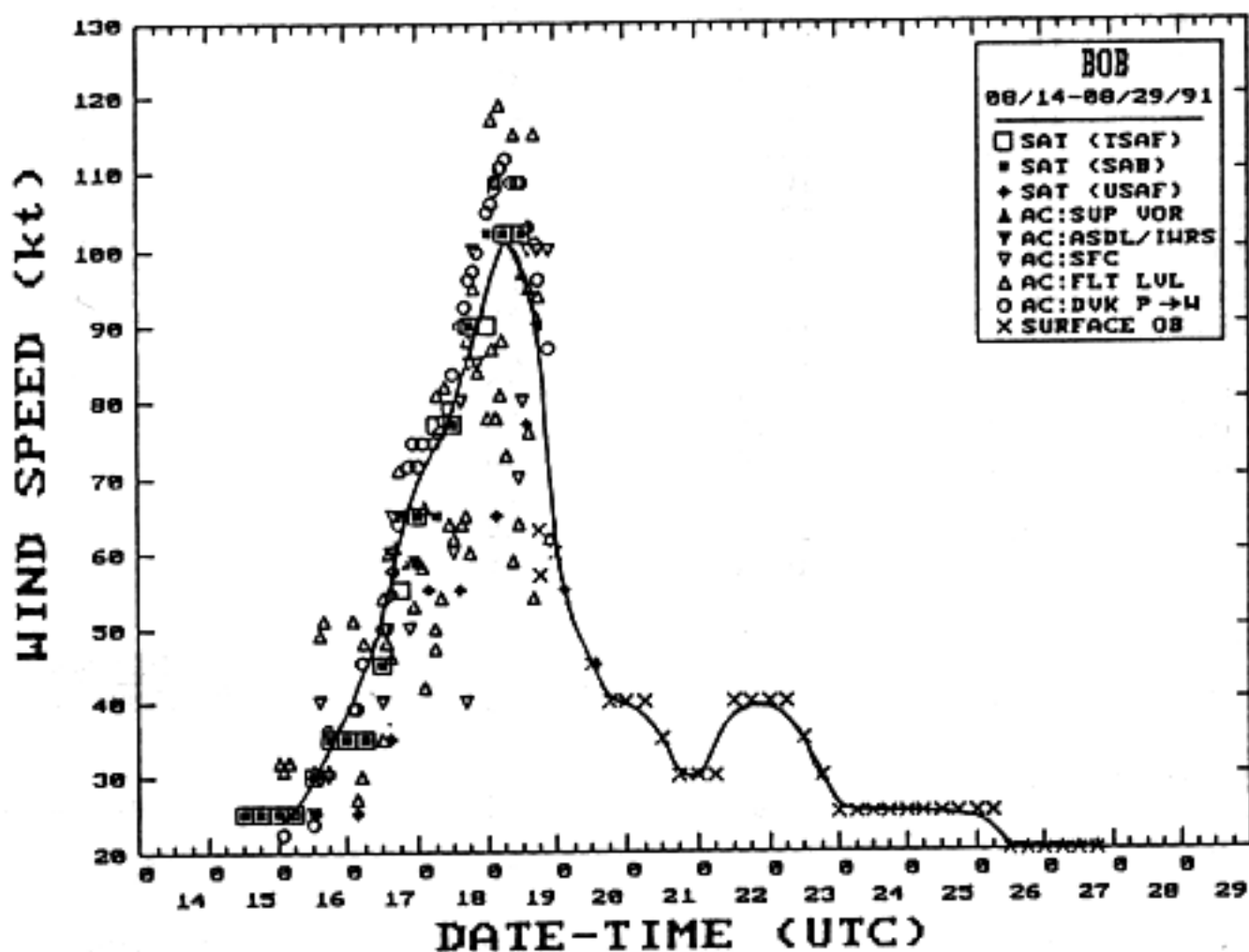


Fig. 3. Best track maximum sustained wind speed curve for Hurricane Bob. Not all aircraft observations are sampling of the maximum wind.

Table 1. Preliminary best track, Hurricane Bob, 16-20 August 1991.

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
16/0000	25.6	74.3	1014	25	Tropical Depression
0600	25.7	74.9	1012	25	" "
1200	25.9	75.4	1010	30	" "
1800	26.4	75.8	1005	35	Tropical Storm
17/0000	27.1	76.2	1003	40	" "
0600	27.8	76.5	998	45	" "
1200	28.4	76.9	996	55	" "
1800	29.0	77.1	986	65	Hurricane
18/0000	29.7	77.0	980	70	" "
0600	30.5	76.9	979	75	" "
1200	31.5	76.6	974	80	" "
1800	33.0	76.1	965	85	" "
19/0000	34.6	75.3	957	95	" "
0600	36.5	74.5	950	100	" "
1200	38.9	73.0	953	95	" "
1800	41.4	71.4	964	85	" "
20/0000	43.8	69.6	977	60	Tropical Storm
0600	45.6	67.6	987	50	" "
1200	47.0	65.5	998	45	" "
1800	48.4	61.9	1003	40	Extratropical
21/0000	49.8	58.3	1008	40	" "
0600	50.9	54.9	1008	40	" "
1200	51.6	51.4	1009	35	" "
1800	51.9	47.3	1009	30	" "
22/0000	51.9	42.8	1004	30	" "
0600	51.5	38.3	1002	35	" "
1200	50.7	34.1	994	40	" "
1800	49.3	30.3	992	40	" "
23/0000	47.7	26.9	992	40	" "
0600	46.3	23.9	996	40	" "
1200	45.3	21.4	1000	35	" "
1800	44.2	19.9	1004	30	" "
24/0000	43.1	19.4	1006	25	" "
0600	42.4	19.1	1008	25	" "
1200	42.2	18.6	1009	25	" "
1800	42.1	18.1	1009	25	" "
25/0000	41.9	17.9	1009	25	" "
0600	41.7	17.8	1010	25	" "
1200	41.3	17.6	1010	25	" "
1800	40.9	17.3	1010	25	" "
26/0000	40.5	16.8	1010	25	" "
0600	40.2	16.0	1010	25	" "
1200	40.0	15.2	1012	20	" "
1800	39.9	14.4	1012	20	" "
27/0000	39.9	13.8	1014	20	" "
0600	40.0	13.1	1014	20	" "
1200	40.0	12.4	1014	20	" "
1800	40.0	11.8	1014	20	" "
28/0000	40.0	11.3	1015	15	" "
0600	40.0	10.9	1015	15	" "
1200	40.0	10.5	1014	15	" "
1800	40.0	10.1	1014	10	" "
29/0000	40.0	9.9	1015	10	" "
0600					Dissipated
19/0600	36.5	74.5	950	100	Minimum Pressure
Landfall:					
Block Island, Rhode Island					
19/1720	41.2	71.6	962	90	Hurricane
Newport, Rhode Island					
19/1800	41.4	71.4	964	85	Hurricane
Rockland, Maine					
20/0130	44.1	69.1	981	60	Tropical Storm

Table 2a. Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
North Carolina								
Wilmington WSO	1005.5	18/2055	16	26	18/1950			0.68
Wrightsville Beach						2.0		
Atlantic Beach						1.0		
Cedar Island			30	50	19/0100			
Cape Hatteras- Pamlico Sound side	985.0	19/0200	44	64	19/0257	2.6-4.9		5.30
Duck			54	58	19/0446	1.4		
Virginia								
Norfolk WSO	1002.4	19/0650	25	35	19/0350	1.0		0.29
Chesapeake Bay Bridge Tunnel						1.1		
Maryland								
Assateague Island								1.77
Ocean City	999.0	19/1010	35	55	19/1015	1.2		
Delaware								
Indian River Coast Guard Station			34	45	19/1100			1.18
Georgetown State Police								0.81
Bridgeville State Police								
Cape Henlopen	1003.4	19/1359						1.67
Lewes State Police	1004.4	19/1415				1.3		
Lewes								1.84
Dover AFB								0.52
Odessa State Police								0.44
Wilmington WSO			14	21	19/1431			
Break Water Harbor						0.9		
New Jersey								
Sandy Hook						2.3		
Ocean City				51	19/1240			
Ventnor City			26	38	19/1120	1.6		2.26
Fishing Pier								
Atlantic City WSO	997.4	19/1325	26	32	19/1350			1.32
State Marina in Atlantic City			26	36	19/1146			2.86
Loveladies				56	19/1245			
Seaside Heights				45	19/1235			
Newark Arpt	999.9	19/1650	22	28	19/1350			2.17
Morristown	1002.7	19/1555	15	25	19/1645			

Table 2a (cont.). Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
New Jersey (cont.)								
Caldwell	1001.4	19/1645	15		19/1454			
Teterboro	1001.0	19/1645	14	22	19/1345			
Englewood								3.02
Forked River								2.97
Paramus								2.83
Garfield								2.43
Marlboro								2.02
Bridgewater								1.57
Clifton								1.56
Chatham								1.53
New Providence								1.52
Stanhope								1.37
Bloomington								1.28
Lebanon								1.05
Washington								0.91
New York								
Farmingdale	995.2	19/1520	42	63	19/1520			
Westhampton Beach	984.8	19/1545	28	52	19/1545			
Islip	991.6	19/1550	30	42	19/1550			5.91
La Guardia Arpt	1000.0	19/1550	27	44	19/1550			2.77
JF Kennedy Arpt	997.6	19/1442	26	40	19/1450			2.60
White Plains	1000.0	19/1545	18	30	19/1510			2.91
Fire Island	989.5	unknown	55	65	unknown			
Eatons Neck	999.7	19/1600	45		19/1600			
Rockaway	999.0	19/1400	30	55	19/1400			
Montauk Coast Guard	968.5	19/1700	60	75	19/1800		10(est.)	3.89
Montauk Lighthouse				88	19/1640			
Montauk Harbor			50		19/1705			
9 n mi west of Montauk Lighthouse	967.5	19/1705	30		19/1212			
Nicoll Bay	992.2	19/1705	35	50	19/1705			
Mount Sinai			40	55	19/1705			6.25
Bartletts Reef			35		19/1705			
Tobay Beach	1001.4	19/1705	35		19/1705			
Ambrose Tower			41		19/1705			
South Shore	1001.4	19/1705	20		19/1705			
Raritan Bay								
Hitherhills State Park				76	unknown			
West Gilgo Beach				61	unknown			

Table 2a (cont.). Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
New York (cont.)								7.04
Bridgehampton								6.80
East Hampton								6.40
Brookhaven Lab	987.1	19/1630		58	19/1730			4.80
Noyack								4.70
Mattituck								4.11
Mattituck South								4.00
Babylon								6.50
Bethpage								6.00
Plainview								4.14
Mineola								3.15
Valley Stream								3.00
New Hyde Park						6.7		
Willetts Point								2.95
Oceanside								2.47
Brooklyn Marine Park						1.8		
The Battery								3.90
Valley Cottage								3.10
Tappan								3.07
Pearl River								2.60
Sparkill								2.52
Mount Ivy								2.46
West Haverstraw								2.44
New City								2.42
Pomona								2.25
Chestnut Ridge								3.16
Pelham Manor								2.72
Yorktown								1.81
Peekskill								1.49
Ardsley								5.00
Middletown								1.49
Port Jervis								
Connecticut								4.72
Bridgeport WSO	992.1	19/1728	24	45	19/1550			
Bridgeport NOS gage						4.8		3.62
Thomaston								4.05
Hartford WSO	994.2	19/1730	32	48	19/1838			
Hartford Brainard Field				35	19/1546			5.73
Wethersfield				56	19/1730			5.04
Glastonbury								

Table 2a (cont.). Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
Connecticut (cont.)								
Bristol								5.40
Mansfield								6.02
Ellington								3.78
Plainfield								5.82
Putnam								5.01
Thompson								5.03
Mystic	977.0	unknown				4 (est.)		
New London						5.0		
Groton Long Point						4 (est.)		
Stonington				53	unknown			5.77
Norwich								5.62
Groton EOC								7.00
U.S. Coast Guard Cutter Pt. Knoll (5 n mi SW of Groton)			65	87	unknown			
Rhode Island								
Providence WSO	972.5	19/1815	36	55	19/1727			2.51
Providence NOS gage						6.6		
Providence Hurricane Barrier						6.5		
Scarborough State Beach							13.7	
Sakonnet Point				87	unknown		10.2-16.5	
Newport							6.0-14.6	
Newport NOS gage						5.5		
Newport State Airport			65	83	unknown			
Narragansett			78	87	unknown		13.7	
Westerly State Airport			44	65	19/1645			
Block Island	966.0	19/1720		91***	19/1630			
Block Island Power Station				87***	19/1715			
Narragansett Bay								
USS VALDEZ 41.5°N 71.3°W	964.0	19/1815	63	75	19/1730			
USS SAMUEL B. ROBERTS 41.6°N 71.3°W	967.5	19/1825	63	82	unknown			
USS CAPODANNO 41.5°N 71.4°W	967.2	19/1757	57		19/1656			
Adamsville	964.1	19/1820		60	unknown			0.59

Table 2a (cont.). Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
Rhode Island (cont.)								5.21
Clayville								3.55
Woonsocket								7.01
Foster								6.23
Ashaway	982.4	unknown		75	19/1910			
West Warwick				87	unknown			
Warwick EOC	971.2	unknown		74	unknown			
Middletown	971.9	19/1830		71	19/1659			
Point Judith	965.8	unknown		74	unknown			
Massachusetts								
Chatham	982.7	19/1900	64	83	19/1945		11.1-14.9	0.18
Westover AFB	994.2	19/1826		50	19/1823			4.05
Brimfield								5.43
Ware								3.97
Milton	974.6	19/1945	54	68	19/1832			2.58
Blue Hill Observatory								
Boston	976.3	19/1959	41	56	19/1909			2.21
Cape Cod Canal							8.5-13.0	
New Bedford			75	96	19/1820	5.8		
Hurricane Barrier								
Provincetown	976.0	19/1945	85	95	19/1935			
NOAA Ship OREGON II								
South Weymouth	970.9	19/1945						
Naval Air Station								
Cape Cod-Coast Guard	984.3	19/1845						
Air Station								
Otis Air Natl Guard			48	82	19/1855			
Mattapoissett							9.9-13.3	
Wareham							8.5-15.3	
Onset							11.4-12.1	
Pocasset							10.0-12.6	
Woods Hole						5.8		
Blackstone				40	19/2000			4.29
Plymouth Bay				74	19/1850			
Boston Harbor				62	19/1845	3.6		
Nahant				59	19/1855			
Plum Island				53	19/2140			

Table 2a (cont.). Hurricane Bob selected surface observations, August 1991.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	1-minute average	Peak gust	Date/time (UTC)*			
New Hampshire								
Concord	993.8	19/2051	29	37	19/2037			3.98
Pease AFB				52	19/2213			
Nashua				50	19/2045			
Manchester				46	19/2045			
Keene				36	19/1935			
Laconia				31	19/2314			
Lebanon				19	19/1750			
Maine								
Portland	985.1	19/2258	35	53	19/2250	2.5		7.83
Rockland	981.0	20/0114						
Kennebunkport						2.4		
Biddeford						3.8		
Wiscasset			61	80	19/2300			
Blue Hill			57	81	20/0000			
Booth Bay	982.5	20/0045		50	19/2203			2.75
CANADA								
Nova Scotia								
Yarmouth			25	43	20/0200			2.24
Digby			38	59	20/0500			
Halifax			26	37	20/0900			
Amherst	1002.7	20/0900	35	52	20/1200			
New Brunswick								
St. John	999.8	20/0700	35	52	20/0642			1.29
Fredericton	995.7	20/0700	20	37	20/0200			1.80

* Time of 1-minute wind speed unless only gust is given.

** Storm surge is water height above normal tide level. Storm tide is water height relative to National Geodetic Vertical Datum (NGVD) which is defined as mean sea level in 1929.

*** Value was at upper limit of equipment range.

Table 2b. Unofficial wind reports on Hurricane Bob, August 1991.

Location	Maximum surface wind speed (knots)		
	sustained	Peak gust	Date/time (UTC)*
Massachusetts			
Edgartown		97	unknown
Edgartown		82	19/1730
Cape Pogue	78	96	19/1745
Nantucket	74	89	19/1917
Woods Hole	74	109	19/1730
Ship Betty Schouest			
Falmouth		87	19/1830
East Falmouth		82	19/1830
East Falmouth		52	unknown
Centerville	65	72	19/1830
West Yarmouth		76**	unknown
West Yarmouth		78	unknown
South Yarmouth		97	unknown
South Dennis		71**	19/1840
Harwich Port		85	19/1800
Harwich Port	65	78	19/2000
South Harwich	52	69	19/1900
South Chatham	65	76	19/1900
South Chatham	74	82	unknown
Chatham	71	80	19/1900
Chatham	56	61	19/1900
East Orleans	78		19/1900
North Eastham	61	65	19/1930
Truro		80	19/2015
North Truro	69	89	19/1900
North Truro	87	104	19/1930
North Truro	78	87	19/1930
Provincetown	85	87**	19/1915
Brewster	65	109	19/2000
Brewster		104	19/1930
East Sandwich	55	71	19/1900
East Sandwich		75	19/1830
Sandwich	56	74	19/1900
Sandwich	40	69	19/1745
Sagamore Beach	56	68	19/1900
Buzzards Bay	78	100	19/1740
Bourne		85	unknown
Pocasset	43	64	19/1900
North Falmouth		87**	unknown
West Falmouth	55	82	19/1800
Forestdale	65	74	19/1800
Westport		81	unknown

* Time of sustained wind speed unless only gust is given.

** Value was at upper limit of equipment range, or equipment became inoperable beyond this value.

Table 2c. Hurricane Bob selected NDBC observations, August 1991.

Platform/ Location	Minimum sea-level pressure		Maximum wind speed (knots)		
	Pressure (mb)	Date/time (UTC)	average*	Peak gust	Date/time (UTC)
Cape Lookout C-MAN CLKN7 / 34.6°N 76.5°W	998.3	19/0000	31	40	18/2200
Diamond Shoals C-MAN DSLN7 / 35.2°N 75.3°W	962.1	19/0200	85	97	19/0300
Chesapeake Light C-MAN CHLV2 / 36.9°N 75.7°W	998.2	19/0700	47	52	19/0500
Delaware Bay Buoy 44009 / 38.4°N 74.7°W	994.8	19/1000	43	54	19/1000
Five Fathom Buoy 44012 / 38.8°N 74.6°W	994.9	19/1100	46	57	19/1100
Long Island Buoy 44025 / 40.3°N 73.2°W	987.3	19/1500	44	62	19/1600
Ambrose Light C-MAN ALSN6 / 40.5°N 73.8°W	997.5	19/1500	44	48	19/1500
Nantucket Buoy 44008 / 40.5°N 69.4°W	1000.6	19/1700	47	58	19/1900
Buzzards Bay C-MAN BUZM3 / 41.4°N 71.0°W	970.8	19/1800	67	77	19/1700
Boston Buoy 44013 / 42.4°N 70.8°W	973.4	19/2000	45	59	19/1900
Gulf of Maine Buoy 44005 / 42.7°N 68.6°W	992.6	19/2300	44	55	19/1900
Isle of Shoals C-MAN IOSN3 / 43.0°N 70.6°W	975.3	19/2100	47	52	19/2100
Portland Buoy 44007 / 43.5°N 70.1°W	979.9	19/2300	41	53	19/2100
Matinicus Rock C-MAN MISM1 / 43.8°N 68.9°W	983.3	20/0100	56	64	20/0100
Mt Desert Rock C-MAN MDRM1 / 44.0°N 68.1°W	990.6	20/0200	52	61	20/0200

*NOAA buoys report an 8-minute average wind and C-MAN stations report a 2-minute average wind.

Table 3. Watch and warning summary, Hurricane Bob.

Date/Time(UTC) /Action

16/1600 Tropical Storm Warning	Northwest Bahamas from Andros and Eleuthera Islands northward
17/1000 Tropical Storm Warning discontinued	Northwest Bahamas from Andros and Eleuthera Islands northward
17/1600 Hurricane Watch	North Carolina coast from Little River Inlet northward to south of Virginia Beach, Virginia... including Pamlico and Albemarle Sounds
17/2200 Hurricane Warning	North Carolina coast from Little River Inlet northward to south of Virginia Beach, Virginia... including Pamlico and Albemarle Sounds
17/2200 Hurricane Watch	Virginia Beach, Virginia northward to Cape Henlopen, Delaware
18/1600 Hurricane Warning	Virginia Beach, Virginia northward to Cape Henlopen, Delaware
18/1600 Tropical Storm Warning	Lower Chesapeake Bay south of the mouth of the Patuxent River including the greater Norfolk area
18/1600 Hurricane Watch	Cape Henlopen, Delaware to Plymouth, Massachusetts including Long Island and Cape Cod
18/2200 Hurricane Warning	Cape Henlopen, Delaware to Plymouth, Massachusetts including Long Island, Long Island Sound, Connecticut east of New Haven, and Cape Cod
18/2200 Tropical Storm Warning	Delaware Bay
18/2200 Hurricane Watch	Plymouth, Massachusetts northward through Eastport, Maine
19/0400 Hurricane Warning discontinued	South of Cape Lookout, North Carolina
19/1000 Hurricane Warning	Plymouth, Massachusetts to Eastport, Maine
19/1000 Hurricane Warning discontinued	South of Virginia Beach, Virginia
19/1000 Wind and Heavy Rain Warning	Nova Scotia, New Brunswick, and Prince Edward High Island
19/1200 Hurricane Warning discontinued	South of Cape Charles, Virginia
19/1200 Tropical Storm Warning discontinued	Lower Chesapeake Bay including the greater Norfolk area

Table 3 (cont.). Watch and warning summary, Hurricane Bob.

19/1400 Hurricane Warning discontinued	South of Cape May, New Jersey
19/1400 Tropical Storm Warning discontinued	Delaware Bay
19/1600 Hurricane Warning discontinued	South of Manasquan Inlet, New Jersey
19/1800 Hurricane Warning discontinued	South of Fire Island, New York
19/2000 Hurricane Warning discontinued	South of Watch Hill, Rhode Island
19/2200 Hurricane Warning discontinued	South of Point Judith, Rhode Island
20/0000 Hurricane Warning discontinued	Woods Hole, Massachusetts to Point Judith, Rhode Island
20/0200 All hurricane warnings discontinued	Woods Hole, Massachusetts to Eastport, Maine
20/0200 Tropical Storm Warning	Rockland, Maine to Eastport, Maine
20/0700 Tropical Storm Warning discontinued	Rockland, Maine to Eastport, Maine
20/1000 Heavy Rain Warning discontinued	New Brunswick, Nova Scotia, and Prince Edward Island

Table 4. Hurricane Bob average track forecast errors
(nautical miles), non-homogeneous sample.

Model	Forecast period (hours)				
	12	24	36	48	72
Official (no. of cases)	51 (14)	81 (12)	101 (10)	141 (8)	343 (4)
CLIPER	51 (14)	127 (12)	250 (10)	386 (8)	583 (4)
BAMD	38 (14)	71 (12)	90 (10)	116 (8)	236 (4)
BAMM	51 (14)	90 (12)	114 (10)	145 (8)	299 (4)
BAMS	79 (14)	127 (12)	151 (10)	191 (8)	386 (4)
NHC90	46 (14)	78 (12)	102 (10)	109 (8)	141 (4)
QLM	54 (6)	97 (5)	121 (4)	136 (3)	132 (2)

Table 5. Chances of the center of Hurricane Bob passing within 65 miles of listed locations by date and time (EDT) indicated; probabilities in percent.

	ADVISORY ISSUE TIME: 16/2AM	16/6AM	16/NOON	16/6PM	16/1030PM
	PROBABILITY END TIME: 18/8PM	19/2AM	19/8AM	19/2PM	19/8PM
MUCF 221N 805W	2	3	6	X	X
MUSN 216N 826W	2	2	4	X	X
MUHA 230N 824W	4	5	7	X	X
MUAN 219N 850W	2	2	4	X	X
MYAK 241N 776W	13	15	14	5	X
MYNN 251N 775W	55	39	25	12	X
MYGF 266N 787W	58	43	27	20	4
MARATHON FL	14	13	12	6	X
MIAMI FL	27	23	16	10	X
W PALM BEACH FL	35	28	18	14	X
FT PIERCE FL	29	25	18	15	X
COCOA BEACH FL	23	21	16	15	5
DAYTONA BEACH FL	19	18	14	14	6
JACKSONVILLE FL	15	14	11	12	7
SAVANNAH GA	13	12	8	11	10
CHARLESTON SC	12	11	8	11	14
MYRTLE BEACH SC	10	10	7	11	16
WILMINGTON NC	9	9	6	11	17
MOREHEAD CITY NC	8	8	6	11	17
CAPE HATTERAS NC	6	7	5	10	17
NORFOLK VA	5	5	3	7	14
OCEAN CITY MD	3	3	2	5	11
ATLANTIC CITY NJ	2	2	X	X	10
KEY WEST FL	11	11	11	X	X
MARCO ISLAND FL	18	16	14	X	X
FT MYERS FL	19	17	14	X	X
VENICE FL	18	16	12	X	X
TAMPA FL	18	16	12	X	X
CEDAR KEY FL	16	14	11	X	X
ST MARKS FL	13	X	8	X	X
APALACHICOLA FL	12	X	7	X	X
PANAMA CITY FL	11	X	6	X	X
PENSACOLA FL	8	X	4	X	X
MOBILE AL	7	X	3	X	X
GULFPORT MS	6	X	3	X	X
BURAS LA	5	X	3	X	X
NEW ORLEANS LA	4	X	2	X	X
NEW IBERIA LA	3	X	X	X	X
GULF 29N 85W	12	X	8	X	X
GULF 29N 87W	9	X	5	X	X
GULF 28N 89W	6	X	3	X	X
GULF 28N 91W	4	X	2	X	X
GULF 28N 93W	2	X	X	X	X
MYEG 235N 758W	X	3	7	X	X
MYSM 241N 745W	X	3	7	X	X
MMCZ 205N 869W	X	X	2	X	X
MUCM 214N 779W	X	X	3	X	X
PROVIDENCE RI	X	X	X	X	7
NANTUCKET MA	X	X	X	X	7
HYANNIS MA	X	X	X	X	7
BOSTON MA	X	X	X	X	6
NEW YORK CITY NY	X	X	X	X	8
MONTAUK POINT NY	X	X	X	X	8

Table 5 (cont.). Chances of the center of Hurricane Bob passing within 65 miles of listed locations by date and time (EDT) indicated; probabilities in percent.

	ADVISORY ISSUE TIME: PROBABILITY END TIME: 17/6AM 20/2AM	17/NOON 20/8AM	17/6PM 20/2PM	17/1030PM 20/8PM	18/6AM 21/2AM
MYGF 266N 787W	2	X	X	X	X
FT PIERCE FL	3	X	X	X	X
COCOA BEACH FL	4	X	X	X	X
DAYTONA BEACH FL	5	X	X	X	X
JACKSONVILLE FL	5	5	X	2	X
SAVANNAH GA	9	10	5	4	X
CHARLESTON SC	14	17	17	15	5
MYRTLE BEACH SC	16	20	26	23	23
WILMINGTON NC	17	21	28	26	34
MOREHEAD CITY NC	18	21	28	28	40
CAPE HATTERAS NC	18	19	25	24	36
NORFOLK VA	14	16	19	19	25
OCEAN CITY MD	12	14	16	17	22
ATLANTIC CITY NJ	11	13	15	15	19
TAMPA FL	2	X	X	X	X
CEDAR KEY FL	2	X	X	X	X
ST MARKS FL	2	X	X	X	X
PROVIDENCE RI	9	11	13	13	16
NANTUCKET MA	10	11	13	13	17
HYANNIS MA	9	11	13	13	16
BOSTON MA	8	10	13	13	15
NEW YORK CITY NY	10	12	14	14	17
MONTAUK POINT NY	10	11	14	14	17
SABLE ISLAND NS	4	X	7	7	9
SYDNEY NS	3	X	8	8	10
EDDY POINT NS	4	5	9	9	11
PTX BASQUES NFLD	2	X	7	7	10
BURGEO NFLD	2	X	7	7	9
ILE ST PIERRE	2	X	6	6	9
PORTLAND ME	7	9	12	12	13
BAR HARBOR ME	6	8	11	11	13
EASTPORT ME	6	8	11	11	13
ST JOHN NB	5	7	11	10	12
MONCTON NB	4	6	10	10	12
YARMOUTH NS	7	8	11	11	13
HALIFAX NS	5	6	10	10	12
CAPE RACE NFLD	X	X	3	4	6
HIBERNIA OILFLD	X	X	X	2	4

Table 5 (cont.). Chances of the center of Hurricane Bob passing within 65 miles of listed locations by date and time (EDT) indicated; probabilities in percent.

	ADVISORY ISSUE TIME: 18/NOON PROBABILITY END TIME: 21/8AM	18/6PM 21/2PM	18/1030PM 21/8PM	19/6AM 22/2AM	19/NOON 22/8AM
MYRTLE BEACH SC	6	X	X	X	X
WILMINGTON NC	27	7	X	X	X
MOREHEAD CITY NC	50	61	99	X	X
CAPE HATTERAS NC	51	77	99	X	X
NORFOLK VA	29	30	35	X	X
OCEAN CITY MD	25	34	41	99	3
ATLANTIC CITY NJ	21	27	30	30	7
PROVIDENCE RI	20	33	37	69	85
NANTUCKET MA	20	35	40	49	55
HYANNIS MA	20	34	39	59	70
BOSTON MA	18	30	33	64	75
NEW YORK CITY NY	19	26	27	40	23
MONTAUK POINT NY	21	35	40	73	99
SABLE ISLAND NS	8	6	5	X	X
SYDNEY NS	10	12	13	8	4
EDDY POINT NS	11	13	14	8	3
PTX BASQUES NFLD	11	13	15	12	8
BURGEO NFLD	10	11	12	9	5
ILE ST PIERRE	8	7	7	X	2
PORTLAND ME	16	24	27	53	68
BAR HARBOR ME	15	25	28	48	59
EASTPORT ME	15	23	27	39	41
ST JOHN NB	14	22	25	33	29
MONCTON NB	13	20	23	29	24
YARMOUTH NS	15	22	26	20	11
HALIFAX NS	12	16	18	10	4
CAPE RACE NFLD	5	4	4	X	X
HIBERNIA OILFLD	3	3	3	X	X

ADVISORY ISSUE TIME: 19/6PM
PROBABILITY END TIME: 22/2PM

19/1030PM
22/8PM

20/6AM
23/2AM

BOSTON MA	X	6	X
SYDNEY NS	X	5	5
EDDY POINT NS	X	3	X
PTX BASQUES NFLD	4	14	21
BURGEO NFLD	2	10	13
ILE ST PIERRE	X	5	X
PORTLAND ME	99	99	X
BAR HARBOR ME	69	99	X
EASTPORT ME	37	64	X
ST JOHN NB	21	42	X
MONCTON NB	18	40	66
YARMOUTH NS	3	4	X
HALIFAX NS	X	2	X
CAPE RACE NFLD	X	3	X
HIBERNIA OILFLD	X	2	X