

Tropical Cyclone Report
Hurricane Gustav
8 - 12 September 2002

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Hurricane Gustav was a category 2 hurricane of subtropical origin. The cyclone passed near the Outer Banks of North Carolina as a tropical storm, then passed over the eastern end of Nova Scotia and western Newfoundland as a category 1 hurricane.

a. Synoptic History

An area of showers developed between the Bahamas and Bermuda on 6 September in association with a developing upper-level trough and a weak surface trough. The upper-level trough amplified over the next two days in response to upstream ridging enhanced by Tropical Storm Fay over the Gulf of Mexico. As this occurred, convection increased in both coverage and intensity and the surface trough became better defined. A broad surface low formed in the system late on 7 September. By 1200 UTC 8 September, the cyclone had developed sufficient organized convection to qualify as a subtropical depression about 440 n mi south-southeast of Cape Hatteras, North Carolina. Later that day, an Air Force Reserve Hurricane Hunter aircraft investigated the cyclone and found it had become Subtropical Storm Gustav. The “best track” chart of the tropical cyclone’s path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1.

Gustav moved erratically west-northwestward on 9 September as it slowly strengthened. On that day, the cyclone had a large area of light winds near the center with multiple low-level cloud swirls, and aircraft and satellite position fixes often differed by 30-50 n mi. Gustav turned north early on 10 September as convection became better organized near the center. Based on this and the development of a band of strong winds closer to the center, it is estimated that the cyclone transformed into a tropical storm around 1200 UTC. Maximum sustained winds reached 55 kt while the center passed between Cape Hatteras and Diamond Shoals, North Carolina about 2100 UTC that day. It should be noted that while the circulation center stayed offshore (not a “landfall”), the radius of maximum winds (RMW) passed over portions of the Outer Banks and thus counts as a “strike” for this area.

Gustav turned northeastward when it reached the Hatteras area, then accelerated northeastward on 11 September in southwesterly flow caused by baroclinic cyclogenesis over the New England states and southeastern Canada. In a complex process similar to that seen in Hurricane Michael in 2000, the tropical cyclone intensified as it gradually began to merge with or absorb the non-tropical low. Gustav became the 2002 season’s first hurricane just before 1200 UTC and reached a maximum intensity of 85 kt near 1800 UTC. After that, the cyclone began to weaken. Gustav made landfall over the southern part of Cape Breton, Nova Scotia near 0430 UTC 12 September as

an 80-kt hurricane. Satellite, surface, and radar data indicated the cyclone was becoming extratropical as it made a second landfall over southwestern Newfoundland near 0900 UTC. Gustav lost all tropical characteristics by 1200 UTC as it continued northeastward while decelerating across Newfoundland. The remnant extratropical low moved into the Labrador Sea, where it turned northwestward late on 13 September and dissipated on 15 September.

b. Meteorological Statistics

Observations in Gustav (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) and the U. S. Air Force Weather Agency (AFWA), as well as flight-level and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Additionally, there were many observations from ships, buoys, and land stations.

The maximum winds reported in Gustav were flight-level winds of 104 kt from both Air Force Reserve (at 850 mb) and NOAA (at 700 mb) hurricane hunters around 1900-2000 UTC 11 September. Using standard flight-level to surface reduction for eyewall conditions, the NOAA report would yield a surface wind estimate of 90-95 kt (Fig. 2). However, neither aircraft reported an eye or eyewall, so a more conservative reduction for convective bands would yield a surface wind estimate of 85-90 kt. This is in better agreement with the 80-85 kt estimated surface wind from the Air Force aircraft and with an 83 kt surface wind measured by the Stepped Frequency Microwave Radiometer instrument on the NOAA aircraft. The minimum aircraft-reported pressure on a formal fix was 969 mb at 1701 UTC 11 September. However, a dropsonde released later that day near the flight-level wind maximum southeast of the center reported a surface pressure of 964 mb. This suggests that the rapid northeastward motion displaced the wind center of the cyclone to the northwest of the pressure center.

Gustav affected many ships and buoys between North Carolina and Nova Scotia, with selected observations given in Table 2. The most notable observations were from the ship **Tellus** (call sign WRYG), which reported 88 kt and 90 kt winds at 1500 and 1600 UTC 11 September. While these winds are not totally inconsistent with the strength of Gustav at the time, the ship was far enough from the center that the speeds appear somewhat suspect. The oil rig WCY533 near Sable Island reported 74 kt winds and a 965.0 mb pressure at 0300 UTC 12 September. Other noteworthy ship and buoy reports include a 55 kt wind reported by the **Columbus Canterbury** (call sign ELUB8) near the North Carolina coast at 1900 UTC 10 September and a 964.3 mb pressure from Canadian buoy 44142 at 2300 UTC 11 September.

Gustav brought tropical-storm winds to portions of the North Carolina coast and eastern Nova Scotia. In North Carolina, the Coastal Marine Automated Network station at Diamond Shoals reported 52 kt sustained winds with a gust to 61 kt at 1400 UTC 10 September and a 984.8 mb pressure at 2000 UTC. The Cape Hatteras Coast Guard station reported a gust of 68 kt at 2130 UTC. In Nova Scotia, Sable Island reported 48 kt sustained winds with a gust to 66 kt at 0414 UTC 12 September, while Hart Island reported a pressure of 961.4 mb at 0345 UTC. Tropical-storm winds were also reported on Prince Edward Island as the wind field of Gustav expanded during

extratropical transition.

Storm surge flooding of 5-6 ft above normal tide levels occurred along the inland side of the Outer Banks in Hyde and Dare counties. This occurred during a period of strong northwesterly winds following the passage of the center of Gustav. Storm tides of 3-4 ft above normal were reported in Cedar Island and along the Neuse River. Tides were 1-2 ft above normal elsewhere along the coasts of North Carolina and southeastern Virginia. A 4-5 ft storm surge occurred at Charlottetown, Prince Edward Island. Above normal tides were also reported along the coasts of northern and eastern Nova Scotia and eastern New Brunswick.

Storm total rainfalls were 2-5 in over portions of the Outer Banks, Nova Scotia, and Prince Edward Island. This included a 4.90 in total at Ocracoke, North Carolina and a 4.25 in total at Lyon's Brook, Nova Scotia. One tornado occurred during Gustav near Ocracoke.

c. Casualty and Damage Statistics

Gustav directly caused one death - a swimmer at Myrtle Beach, South Carolina who suffered injuries from high surf and died two days later. Forty people had to be rescued from storm surge in Hatteras at the height of the storm.

Damages from Gustav were minor. Damages to property and vehicles in North Carolina is estimated at about \$100,000. In Canada, the worst damage occurred on Prince Edward Island, where whole trees were toppled and local flooding occurred. In Nova Scotia, some docks were damaged and trees were blown down.

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Gustav were 50 (13), 70 (11), 66 (9), 112 (7), and 239 (3) n mi for the 12, 24, 36, 48, and 72 h forecasts, respectively. These errors are lower than the average official track errors for the 10-yr period 1992-2001 (43, 81, 115, 148, and 222 n mi, respectively) for 24, 36, and 48h, and higher than the 10-yr average at 12 and 72 h. (Table 4).

Several of the numerical guidance models performed well during Gustav. The National Weather Service Global Forecasting System model (AVNO) had overall best performance, with average track forecast errors of less than 60 n mi through 48 h and a 110 n mi error at 72 h.

Average official intensity errors were 5, 7, 9, 12, and 22 kt for the 12, 24, 36, 48, and 72 h forecasts, respectively. For comparison, the average official intensity errors over the 10-yr period 1992-2001 are 7, 11, 14, 16, and 19 kt, respectively. The largest intensity forecast errors occurred during Gustav's northeastward acceleration, when the intensities were underforecast.

Table 5 lists the U. S. watches and warnings associated with Gustav. A tropical storm watch was issued for portions of the North Carolina coast at 2100 UTC 8 September, while a tropical storm

warning was issued for much of the watch area at 0300 UTC 9 September. This was 48 and 42 h, respectively, before the closest approach of the center to the Cape Hatteras area. In addition to the warnings in table 5, the Canadian Hurricane Center in Halifax, Nova Scotia issued warnings for wind rain and storm surge for large portions of New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island.

Acknowledgments

Much of the U. S. data in this report was contributed by the National Weather Service forecast offices in Wilmington, North Carolina, Morehead City, North Carolina, and Wakefield, Virginia. Peter Bowyer of the Canadian Hurricane Center and Chris Fogarty of Dalhousie University contributed much of the Canadian data.

Table 1. Best track for Hurricane Gustav, 8 - 12 September 2002.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
08/ 1200	29.0	71.0	1009	30	subtropical depression
08 / 1800	30.2	71.1	1007	35	subtropical storm
09 / 0000	30.5	72.3	1004	40	"
09 / 0600	31.2	72.6	1003	40	"
09 / 1200	31.6	73.6	1002	40	"
09 / 1800	31.9	74.5	1002	40	"
10 / 0000	32.1	75.5	996	45	"
10 / 0600	33.0	75.5	990	50	"
10 / 1200	33.7	75.4	987	50	tropical storm
10 / 1800	35.0	75.4	985	55	"
11 / 0000	35.5	74.7	983	55	"
11 / 0600	36.8	73.0	977	60	"
11 / 1200	38.0	70.8	971	70	hurricane
11 / 1800	40.3	66.8	964	85	"
12 / 0000	43.1	62.8	962	80	"
12 / 0600	46.5	59.6	960	75	"
12 / 1200	48.6	57.7	965	60	extratropical
12 / 1800	50.1	55.5	967	60	"
13 / 0000	51.0	54.0	968	55	"
13 / 0600	52.5	52.5	968	50	"
13 / 1200	54.5	51.4	972	45	"
13 / 1800	56.0	49.5	976	45	"
14 / 0000	57.0	51.5	982	40	"
14 / 0600	58.0	52.5	984	35	"
14 / 1200	59.5	53.5	989	30	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
14 / 1800	61.0	54.0	992	30	"
15 / 0000	62.5	54.5	998	20	"
15 / 0600					dissipated
12 / 0400	45.3	60.8	960	80	minimum pressure
12 / 0430	45.6	60.4	960	80	Landfall near Kelpy Cove, Cape Breton Island, Nova Scotia
12 / 0900	47.6	58.6	963	65	Landfall near Rose-Blanche-Harbour le Cou, Newfoundland

Table 2. Selected ship and drifting buoy reports with winds of at least 34 kt for Hurricane Gustav, 8 -12 September 2002.

Date/Time (UTC)	Ship name or call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
08 / 1620	Buoy 41652	30.0	68.8	150 / 43	1012.9
09 / 0300	Buoy 41537	27.4	70.8	210 / 41	1015.4
09 / 0620	Buoy 41652	30.0	68.4	170 / 52	1014.6
09 / 0800	Buoy 41537	27.5	70.8	180 / 56	1014.6
09 / 1500	P&O Nedlloyd Sydney	34.0	76.2	010 / 45	1010.5
09 / 1800	P&O Nedlloyd Sydney	34.6	75.2	030 / 37	1007.5
10 / 1800	Star Inventana	32.6	72.3	250 / 35	1012.4
10 / 1800	Charles Island	33.9	72.8	140 / 35	1003.0
10 / 1900	Columbus Canterbury	35.5	75.0	090 / 55	N/A
11 / 0000	Charles Island	33.0	74.1	250 / 40	1001.5
11 / 0600	WAAH	35.8	72.5	220 / 52	988.5
11 / 1500	Nedlloyd Holland	37.8	66.9	210 / 54	990.5
11 / 1500	Tellus	38.0	68.1	150 / 88	978.0
11 / 1600	Tellus	38.0	68.2	240 / 90	982.3
11 / 1800	Swan	35.0	71.5	240 / 39	1003.7
12 / 0000	P&O Nedlloyd Jakarta	37.2	59.8	220 / 47	1005.0
12 / 0000	Majestic Maersk	40.7	61.6	220 / 40	988.0
12 / 0300	WCY533	44.0	60.3	190 / 74	965.0
12 / 0600	Choyang Zenith	37.0	59.9	230 / 41	1004.5
12 / 0600	YJRX2	44.2	59.6	240 / 55	978.7
12 / 1200	Albatros	44.1	63.8	320 / 48	993.2
12 / 1200	Algofax	46.6	59.5	290 / 43	976.0
12 / 1200	3FPK7	46.6	48.0	210 / 38	995.6
12 / 1500	HP6038	46.4	48.4	190 / 40	994.7
12 / 1800	Kometik	43.4	53.9	230 / 55	992.0
12 / 1800	Atlantic Concert	46.3	50.2	160 / 36	990.9
12 / 2100	Buoy 44602	44.5	52.8	250 / 39	N/A
13 / 0300	HP6038	46.4	48.4	230 / 45	999.5
13 / 0600	Atlantic Concert	45.6	53.4	260 / 50	1004.2
13 / 0900	3FPK7	46.6	48.0	250 / 39	1005.7
13 / 1200	Canmar Success	49.7	45.7	200 / 42	1002.5
13 / 1800	Canmar Success	50.0	47.4	210 / 45	1005.8

Table 3. Selected surface observations for Hurricane Gustav, 8-12 September 2002.

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)			
North Carolina								
Alligator River Bridge			10/2100		56			
Beaufort (KMRH) ^f	10/1900	999.7	10/2033	32	39			1.95
Cape Hatteras CG			10/2130		68			
Cape Hatteras Fishing Pier	10/2112	985.3	10/2112	37	55			
Cedar Island			10/2130		48			
Duck (NOS)	10/2324	995.0	10/2248	44	55			
Elizabeth City (KECG)	10/2145	999.0	10/2054	26	38			0.61
Frisco (KSHE)	10/1700	987.5	11/0100	25	36			4.72
Manteo (KMQI) ^f	10/2100	993.5	10/2300	35	47			2.27
Nags Head			10/2000		53			
Ocracoke			10/2030		64			4.90
Nova Scotia								
Ashdale								4.13
Hallifax								3.70
Hart Island (CWRN)	12/0345	961.4						
Liverpool								4.02
Lyon's Brook								4.25
Middleboro								3.94
Sable Island (CWSA) ^f	12/0300	969.2	12/0414	48	66			
St. Paul's Island (CWEF) ^f	12/0500	961.6	12/0742		66			
Prince Edward Island								
Charlottetown			12/0245	35	52	4-5		2.76
Buoys and C-MAN								
Buoy 41001	11/0600	997.5	11/0310	36 ^e	46			
Buoy 41002	10/0500	996.7	10/1500	29	35			
Buoy 44004	11/1300	977.5	10/1420	44 ^e	62			
Buoy 44008	11/1700	983.1	11/1600	29	35			
Buoy 44011	11/1900	972.4	11/2000	44	61			
Buoy 44014	11/0400	991.3	11/0500	35	44			
Buoy 44137	12/0000	983.6	12/0500	47				
Buoy 44139	12/0500	982.8	12/0600	41				

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)			
Buoy 44142	11/2300	964.3	12/0000	44	60			
Buoy 44145 ^f	12/0900	994.8	13/0000	52				
Buoy 44251	12/1000	984.7	13/0000	37				
Buoy 44255	12/0800	968.1	13/0700	37				
Cape Lookout (CKLN7)	10/1700	996.9	10/2010	31 ^e	40			
Diamond Shoals (DSLN7)	10/2000	984.8	10/1400	52	61			
Duck (DUCN7)	11/0000	997.7	10/2250	46 ^e	57			
Frying Pan Shoals (FPSN7)	10/1000	1002.1	10/0100	44	52			

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

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

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

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

^e 10-min average

^f Incomplete record

Table 4. Preliminary forecast evaluation (heterogeneous sample) for Hurricane Gustav, 8 - 12 September 2002. Forecast errors for tropical storm and hurricane stages (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in bold-face type.

Forecast Technique	Forecast Period (h)				
	12	24	36	48	72
CLP5	88 (13)	202 (11)	301 (9)	421 (7)	421 (3)
GFNI	68 (12)	106 (10)	188 (8)	338 (6)	822 (2)
GFDN*	62 (7)	103 (6)	141 (5)	229 (4)	725 (2)
GFDI	74 (13)	82 (11)	121 (9)	167 (7)	422 (3)
GFDL*	53 (13)	88 (11)	104 (9)	161 (7)	348 (3)
AFW1*	57 (6)	104 (5)	136 (4)	213 (3)	404 (1)
COAI	65 (11)	94 (9)	163 (7)	293 (5)	887 (1)
COAL*	68 (6)	84 (5)	116 (4)	215 (3)	729 (1)
LBAR	60 (13)	121 (11)	203 (9)	309 (7)	411 (3)
A98E	67 (13)	91 (11)	79 (9)	168 (7)	147 (3)
A9UK	70 (6)	68 (5)	84 (4)	200 (3)	104 (1)
BAMD	50 (13)	75 (11)	99 (9)	126 (7)	197 (3)
BAMM	55 (13)	90 (11)	121 (9)	146 (7)	263 (3)
BAMS	69 (13)	113 (11)	157 (9)	183 (7)	372 (3)
AVNI	42 (13)	46 (11)	55 (9)	65 (7)	134 (3)
AVNO*	29 (13)	32 (11)	42 (9)	58 (7)	110 (2)
AEMI	53 (9)	61 (7)	78 (6)	92 (4)	232 (2)
AEMN*	32 (6)	45 (5)	43 (4)	63 (3)	187 (1)
NGPI	81 (13)	66 (11)	109 (9)	155 (7)	307 (3)
NGPS*	40 (13)	61 (11)	78 (9)	124 (7)	402 (3)
UKMI	51 (12)	61 (10)	65 (8)	80 (6)	115 (3)
UKM*	68 (6)	58 (5)	74 (4)	100 (3)	98 (1)
GUNS	63 (12)	65 (10)	78 (8)	95 (6)	138 (3)
GUNA	55 (12)	58 (10)	67 (8)	80 (6)	133 (3)
OFCL	50 (13)	70 (11)	66 (9)	112 (7)	239 (3)
NHC Official (1992-2001 mean)	43 (2199)	81 (1965)	115 (1759)	148 (1580)	222 (1272)

* Output from these models was unavailable at time of forecast issuance.

Table 5. Watch and warning summary for Hurricane Gustav. The table does not include the various watches and warning issued for Canada by Environment Canada.

Date/Time (UTC)	Action	Location
08/2100	Tropical Storm Watch	Cape Fear, NC northward to the NC/VA border including the Pamlico and Ablemarle Sounds
09/0300	Tropical Storm Warning	Cape Fear, NC to Currituck Beach Light, NC including the Pamlico and Ablemarle Sounds
09/0300	Tropical Storm Watch	NC/VA border to Parramore Island, VA and southern Chesapeake Bay south of New Point Comfort, VA
10/0300	Tropical Storm Warning	Currituck Beach Light, NC to Parramore Island, VA and southern Chesapeake Bay south of New Point Comfort, VA
10/1800	Tropical Storm Warning discontinued	west of Surf City, NC
10/2100	Tropical Storm Warning discontinued	west of Bogue Inlet, NC
11/0300	Tropical Storm Warning discontinued	south of Ocracoke Inlet, NC including the Pamlico and Ablemarle Sounds and southern Chesapeake Bay south of New Point Comfort, VA
11/0900	Tropical Storm Warning discontinued	remainder of NC/VA coasts

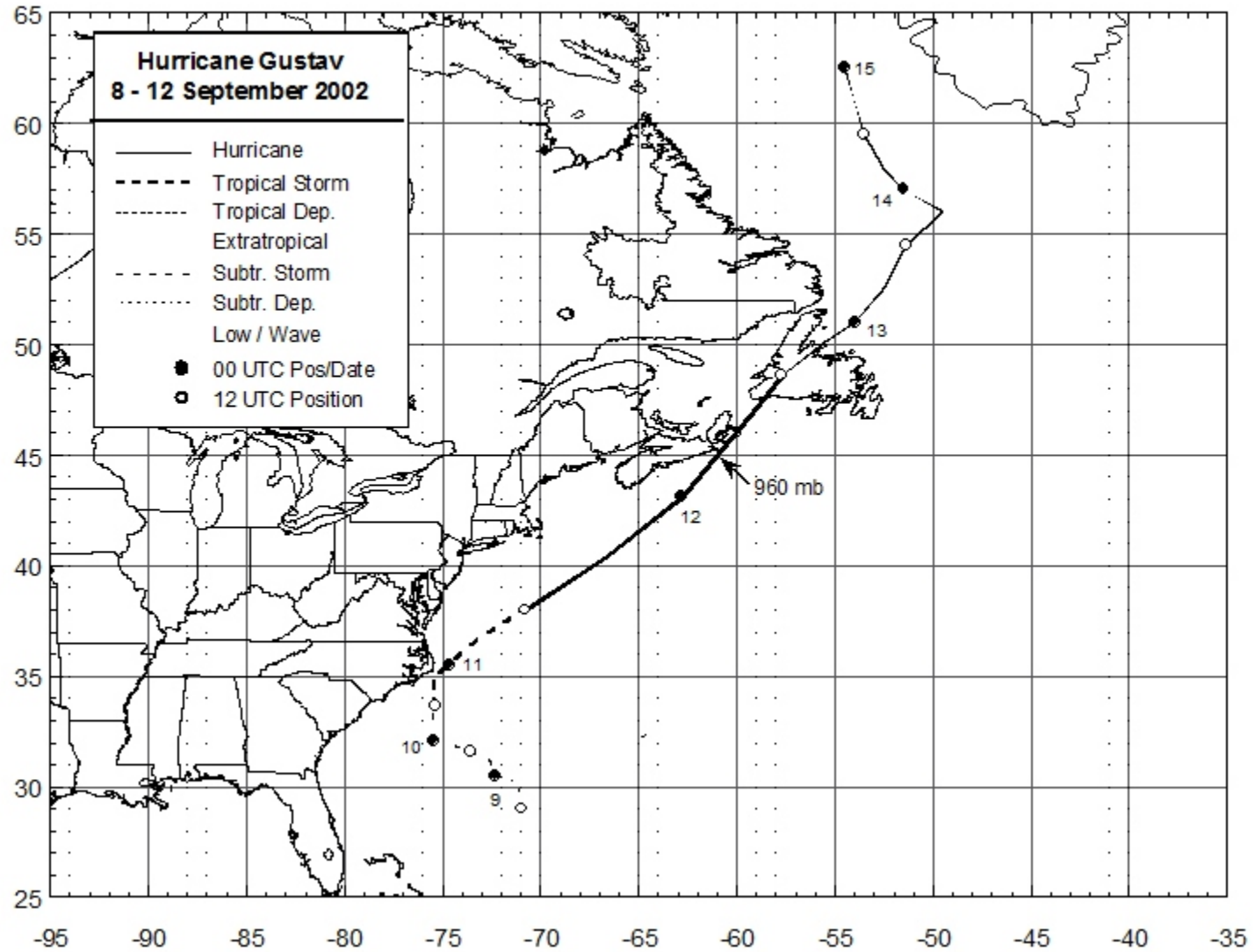
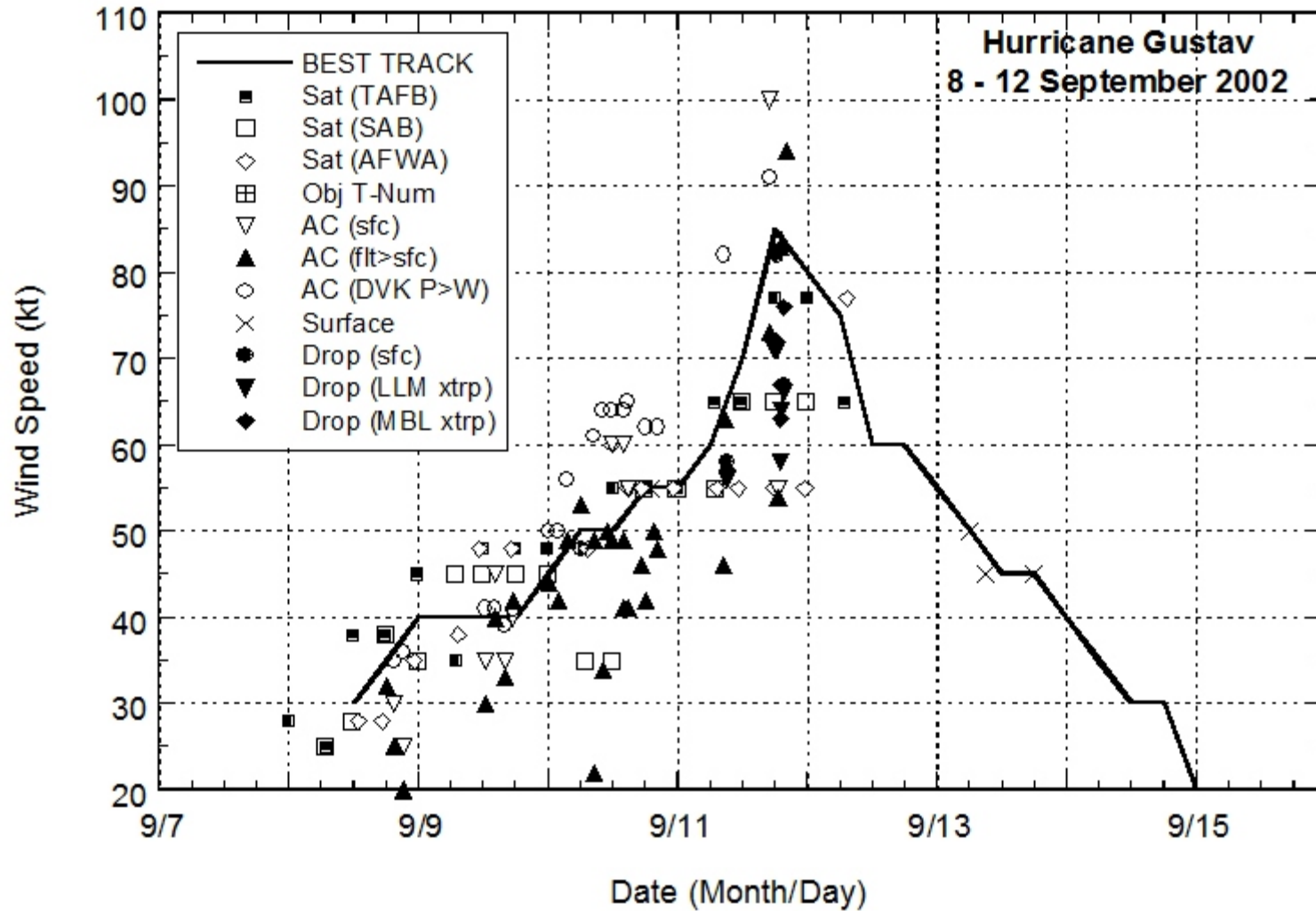


Figure 1. Best track positions for Hurricane Gustav, 8 - 12 September 2002. Track during the extratropical stage is based on analyses from the NOAA Marine Prediction Center.



Figure

Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Gustav, 8 - 12 September 2002. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM), and from the sounding boundary layer mean (MBL). Estimates during the extratropical stage are based on analyses from the NOAA Marine Prediction Center and the Canadian Hurricane Center.

Estimates during the extratropical stage are based on analyses from the NOAA Marine Prediction Center and the Canadian Hurricane Center.