

Tropical Cyclone Report
Hurricane Karl
16 – 24 September 2004

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Karl was a category 4 hurricane on the Saffir-Simpson Hurricane Scale that traveled across the open central North Atlantic.

a. Synoptic History

Karl formed from a strong tropical wave that moved westward from the coast of Africa on 13 September. The system showed increasing shower activity on 14 September, and Dvorak satellite intensity estimates began the next day. The wave spawned a tropical depression around 0600 UTC 16 September about 340 n mi southwest of the southern Cape Verde islands. The “best track” chart of the tropical cyclone’s path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1.

The depression initially moved westward south of a subtropical ridge and strengthened into a tropical storm later that day. Karl turned northwestward on 17 September, then moved west-northwestward while becoming a hurricane the next day. The hurricane continued west-northwestward on 19 September, then turned northwestward on 20 September and north-northwestward on 21 September towards a weakness in the ridge. Maximum sustained winds reached an estimated 115 kt on 20 September and an estimated 125 kt on 21 September. Karl continued moving north-northwestward until 22 September when it turned northeastward in response to a deep-layer baroclinic trough developing north of the hurricane. This motion continued through 23 September. The intensity fluctuated during this time due to a concentric eyewall cycle, with maximum sustained winds decreasing to an estimated 90 kt on 22 September and increasing to an estimated 110 kt the next day. Karl turned northward east of the trough on 24 September and weakened as transition to an extratropical cyclone began. The transition was complete early on 25 September about 510 n mi east of Cape Race, Newfoundland.

As an extratropical low, Karl moved northeastward and eastward across the North Atlantic Ocean and the North Sea, eventually reaching Norway before being absorbed into another extratropical low late on 28 September.

b. Meteorological Statistics

Observations in Karl (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). Microwave satellite imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA QuikSCAT, the NASA Aqua, the Department of Defense Coriolis/Windsat satellite, and Defense Meteorological Satellite Program (DMSP) satellites were also useful in tracking Karl.

Shipping avoided the core of Karl, with reports of winds of tropical storm force from the periphery of the cyclone given in Table 2. The highest reported wind was from the **Rotterdam**, which reported a sustained wind of 45 kt at 1800 UTC 24 September. Two drifting buoys encountered the core of Karl on 24 September. Buoy 41600 reported a pressure of 958.1 mb at 0100 UTC, while buoy 44617 reported a pressure of 964.2 mb at 2100 UTC.

c. Casualty and Damage Statistics

There were no reports of damages or casualties associated with Karl.

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Karl were 37 (31), 65 (29), 84 (27), 101 (25), 118 (21), 125 (17), and 147 (13) n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. These errors are lower than the average official track errors for the 10-yr period 1994-2003¹ (44, 78, 112, 146, 217, 248, and 319 n mi, respectively), (Table 3) – about 20% lower at 12-36 h increasing to 50-60% lower at 96 and 120 h. Some of the track forecast models had average errors lower than the official. These include the GUNA consensus model, which was better at all times except 12 h, and the GFS global model, which was better at all times except 12 and 120 h.

Average official intensity errors were 11, 11, 11, 13, 16, 13 and 11 kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. For comparison, the average official intensity errors over the 10-yr period 1994-2003 are 6, 10, 12, 15, 19, 20, and 21 kt, respectively.

Watches and warnings were not necessary for Karl.

Acknowledgements

Portions of the track of Karl as an extratropical low were provided by the Ocean Prediction Center and the United Kingdom Meteorological Office.

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

Table 1. Best track for Hurricane Karl, 16 – 24 September 2004.

Date/Time (UTC)	Latitude (EN)	Longitude (EW)	Pressure (mb)	Wind Speed (kt)	Stage
16 / 0600	11.2	29.2	1008	30	tropical depression
16 / 1200	11.2	30.7	1007	30	"
16 / 1800	11.2	32.1	1005	35	tropical storm
17 / 0000	11.2	33.3	1002	40	"
17 / 0600	11.6	34.4	997	50	"
17 / 1200	12.1	35.3	994	55	"
17 / 1800	13.0	36.0	992	55	"
18 / 0000	13.9	37.0	984	70	hurricane
18 / 0600	14.5	38.0	975	85	"
18 / 1200	15.0	38.8	970	90	"
18 / 1800	15.6	39.7	965	95	"
19 / 0000	15.9	40.8	965	95	"
19 / 0600	16.0	41.6	960	100	"
19 / 1200	16.3	42.4	955	105	"
19 / 1800	16.7	43.4	951	110	"
20 / 0000	16.8	44.5	951	110	"
20 / 0600	17.0	45.2	948	115	"
20 / 1200	17.5	46.0	951	110	"
20 / 1800	18.1	46.5	951	110	"
21 / 0000	18.7	47.0	943	120	"
21 / 0600	19.6	47.3	938	125	"
21 / 1200	20.8	47.8	943	120	"
21 / 1800	22.3	48.3	948	105	"
22 / 0000	23.7	48.8	955	100	"
22 / 0600	24.9	49.4	962	95	"
22 / 1200	26.2	49.5	967	90	"
22 / 1800	27.5	48.7	970	90	"
23 / 0000	29.0	47.7	965	95	"
23 / 0600	30.7	46.3	951	110	"
23 / 1200	32.5	44.4	953	105	"
23 / 1800	34.5	43.0	955	90	"
24 / 0000	36.8	41.9	957	80	"
24 / 0600	39.5	41.2	959	75	"
24 / 1200	42.6	40.5	961	70	"
24 / 1800	45.5	40.5	962	65	"
25 / 0000	48.1	40.5	963	55	extratropical
25 / 0600	50.4	38.9	967	55	"
25 / 1200	53.0	36.5	973	55	"
25 / 1800	56.1	32.0	980	55	"
26 / 0000	59.5	26.0	986	55	"
26 / 0600	62.0	17.0	983	55	"

Date/Time (UTC)	Latitude (EN)	Longitude (EW)	Pressure (mb)	Wind Speed (kt)	Stage
26 / 1200	63.5	8.0	976	60	"
26 / 1800	64.0	2.0	976	60	"
27 / 0000	64.0	2.5E	980	55	"
27 / 0600	64.5	7.0E	980	45	"
27 / 1200	65.0	10.5E	986	40	"
27 / 1800	65.3	12.0E	989	35	"
28 / 0000	65.5	13.5E	992	30	"
28 / 0600					absorbed by extratropical low
21 / 0600	19.6	47.3	938	125	minimum pressure

Table 2. Selected ship/drifted buoy reports with winds of at least 34 kt for Hurricane Karl, 16 - 24 September 2004.

Date/Time (UTC)	Ship name/ call sign	Latitude (EN)	Longitude (EW)	Wind dir/speed (kt)	Pressure (mb)
21 / 0600	Bering Sea	19.5	43.8	150 / 35	1011.0
21 / 1540	Buoy 13600	22.4	46.8	230 / 39	1000.5
23 / 1200	Lapponian Reefer	27.6	43.1	180 / 44	1011.7
23 / 1500	Star Herdla	31.0	41.4	170 / 41	1007.0
23 / 1800	A8CR8	29.5	40.7	200 / 41	1012.0
23 / 1800	Star Herdla	31.1	41.5	190 / 39	1004.7
24 / 0600	Maersk Durban	36.4	36.0	230 / 41	1009.0
24 / 0600	Santa Maria	42.8	38.1	120 / 39	1002.4
24 / 0900	Colombo Bay	42.5	46.9	010 / 35	1003.1
24 / 1800	Rotterdam	44.4	34.5	150 / 45	1009.3

Table 3. Preliminary forecast evaluation (heterogeneous sample) for Hurricane Karl, 16 – 24 September 2004. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast (OFCL) are shown in bold-face type. Verification includes the depression stage, but does not include the extratropical stage, if any.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	51 (32)	111 (30)	187 (28)	262 (26)	390 (22)	489 (18)	544 (14)
GFDI	31 (30)	51 (28)	62 (26)	73 (24)	110 (20)	153 (16)	188 (12)
GFDL*	39 (30)	56 (28)	64 (26)	72 (25)	107 (21)	147 (17)	165 (12)
GFNI	49 (29)	85 (27)	120 (25)	161 (23)	228 (19)	269 (15)	294 (11)
GFDN*	49 (30)	87 (28)	115 (26)	148 (24)	229 (20)	265 (16)	255 (12)
AFII	38 (24)	62 (22)	80 (21)	103 (19)	120 (15)		
AFW1*	52 (12)	85 (12)	91 (11)	101 (10)	116 (8)		
LBAR	34 (32)	56 (30)	78 (28)	111 (26)	216 (22)	272 (18)	380 (14)
A98E	43 (32)	80 (30)	131 (28)	169 (26)	304 (22)	445 (18)	731 (14)
A9UK	42 (15)	83 (14)	126 (13)	153 (12)	218 (10)		
BAMD	43 (32)	76 (30)	107 (28)	139 (26)	239 (22)	284 (18)	382 (14)
BAMM	48 (32)	84 (30)	118 (28)	151 (26)	222 (22)	226 (18)	305 (14)
BAMS	59 (32)	110 (30)	155 (28)	187 (26)	209 (22)	167 (18)	279 (14)
NGPI	50 (31)	95 (29)	135 (27)	169 (25)	220 (21)	199 (17)	199 (13)
NGPS*	51 (32)	95 (30)	136 (28)	171 (26)	225 (22)	218 (18)	196 (14)
UKMI	49 (27)	82 (25)	102 (23)	128 (21)	199 (17)	173 (13)	302 (10)
UKM*	49 (15)	84 (14)	113 (13)	122 (12)	159 (10)	169 (8)	251 (6)
GFSI	36 (30)	56 (28)	66 (26)	76 (24)	92 (20)	115 (16)	217 (12)
GFS*	37 (31)	59 (29)	69 (27)	76 (25)	97 (21)	110 (17)	183 (13)
AEMI	37 (31)	64 (29)	83 (27)	104 (25)	146 (21)	150 (17)	238 (13)
AEMN*	47 (30)	66 (28)	84 (27)	101 (25)	149 (21)	154 (17)	206 (14)
GUNS	41 (27)	68 (25)	87 (23)	104 (21)	132 (17)	109 (13)	153 (10)
GUNA	38 (27)	60 (25)	74 (23)	89 (21)	117 (17)	97 (13)	137 (10)
CONU	37 (30)	65 (28)	83 (26)	102 (24)	128 (20)	116 (16)	140 (12)
FSSE*	37 (27)	54 (25)	67 (23)	82 (21)	120 (17)	116 (13)	168 (10)
OFCI	39 (30)	65 (28)	86 (26)	99 (24)	131 (20)	137 (16)	165 (12)
OFCL	37 (31)	65 (29)	84 (27)	101 (25)	118 (21)	125 (17)	147 (13)
NHC Official (1994-2003 mean)	44 (3172)	78 (2894)	112 (2636)	146 (2368)	217 (1929)	248 (421)	319 (341)

* Output from these models was unavailable at forecast time.

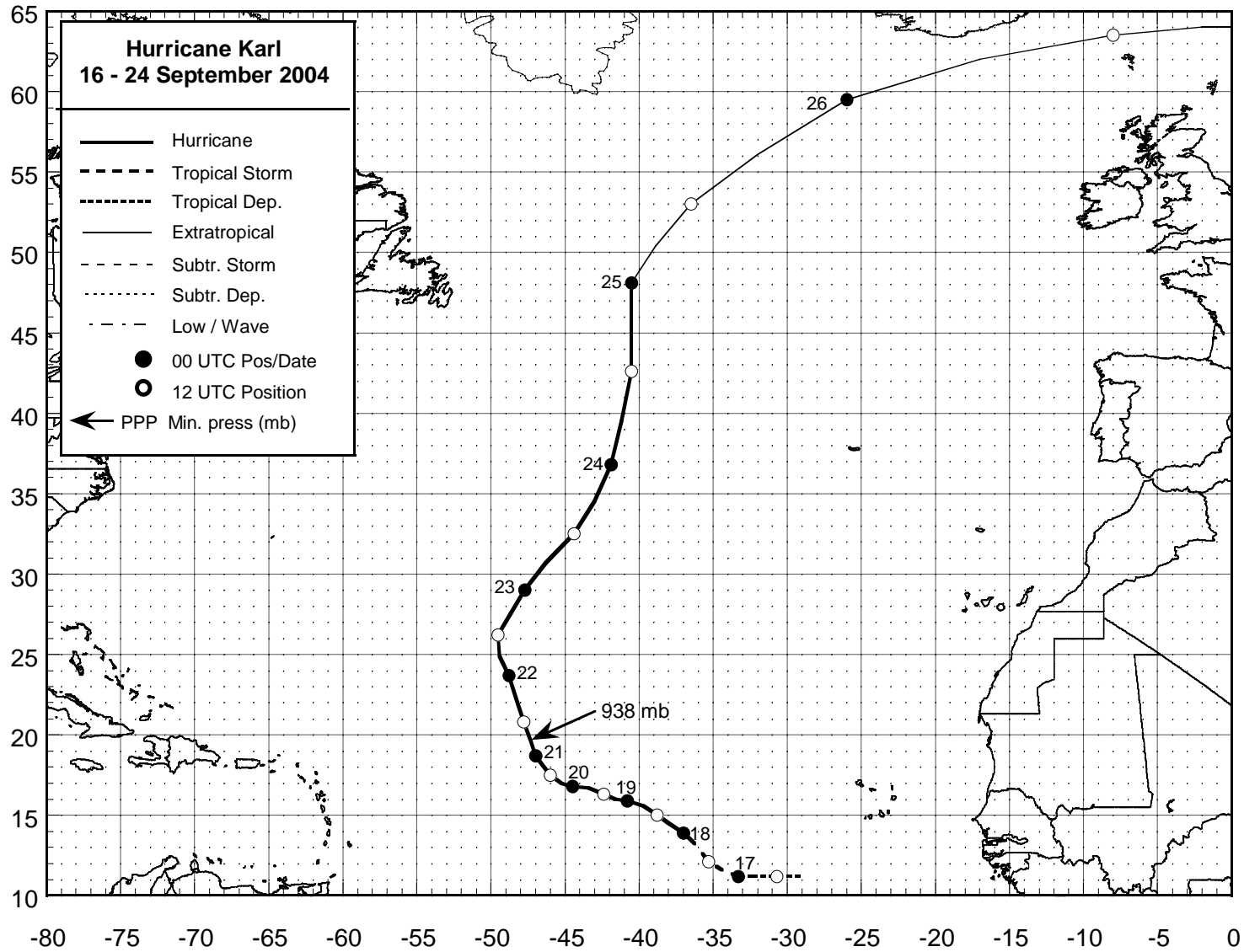


Figure 1. Best track positions for Hurricane Karl, 16 – 24 September 2004. Track during the extratropical stage is based on analyses from the NOAA Ocean Prediction Center and the United Kingdom Meteorological Office.

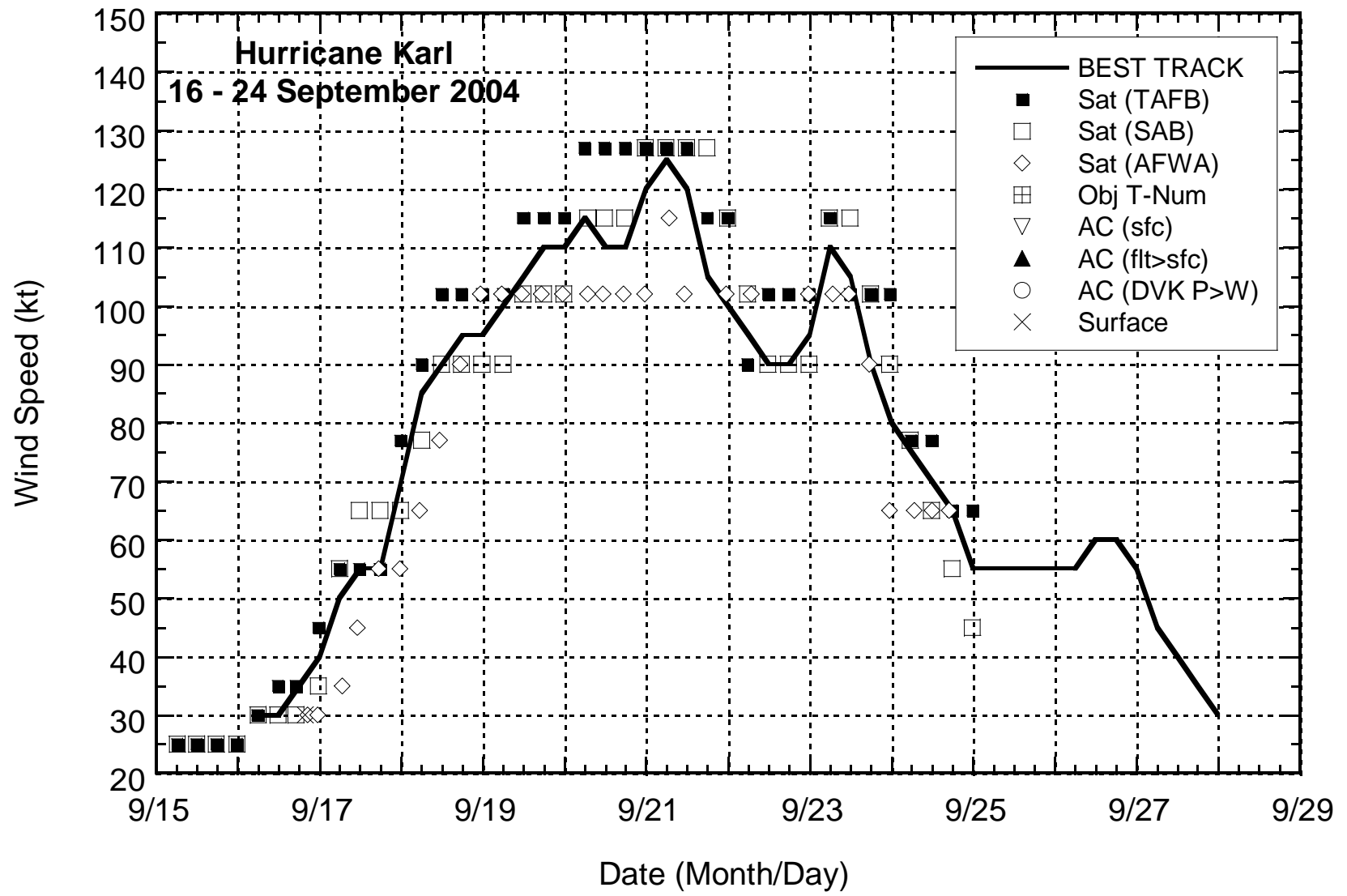


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Karl, 16 – 24 September 2004. Estimates during the extratropical stage are based on analyses from the NOAA Ocean Prediction Center and the United Kingdom Meteorological Office.

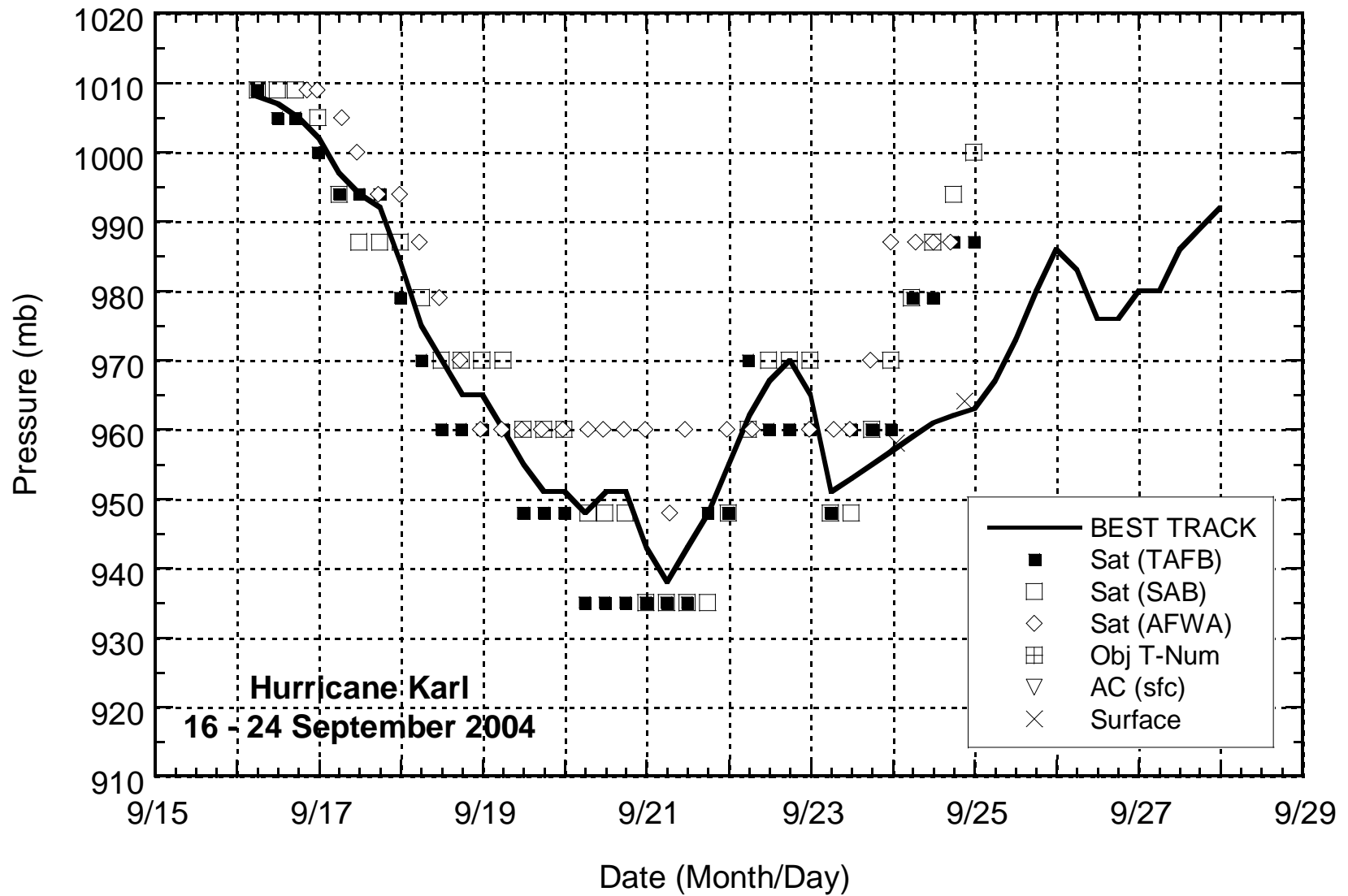


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Karl, 16 – 24 September 2004. Estimates during the extratropical stage are based on analyses from the NOAA Ocean Prediction Center and the United Kingdom Meteorological Office.