

Tropical Cyclone Report
Hurricane Kyle
20 September - 12 October 2002

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Hurricane Kyle was a category 1 hurricane (on the Saffir-Simpson Hurricane Scale) that lasted for 22 days and became the third longest-lived tropical cyclone in the Atlantic basin. Kyle eventually made landfall along the southeastern United States coast as a weak tropical storm before moving back out to sea.

a. Synoptic History

Kyle formed from a non-tropical low pressure system in the central North Atlantic Ocean. A cold front moved across Bermuda on 13 September and stalled to the southeast of the island by 15 September. The stationary front gradually weakened and became an elongated area of low pressure by 18 September. A sharp mid-level shortwave trough moved off the southeast coast of the United States and likely acted as the triggering mechanism for the development of a stationary low pressure center by 1200 UTC 19 September about 750 n mi east-southeast of Bermuda. Thunderstorms gradually developed into narrow bands a few hundred miles away from the well-defined low-level circulation center. Surface winds gradually increased to 25 kt early on 20 September and the overall satellite cloud pattern became much better organized. At 1800 UTC that day, it is estimated that Subtropical Depression Twelve had developed about 715 n mi east-southeast of Bermuda. Later that day, the system made a clockwise loop as it became embedded in the weak steering flow region (or "col") between its parent upper-level low to the south and a mid-latitude trough to the north. 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.

Based on Dvorak satellite intensity values, it is estimated that the cyclone became Subtropical Storm Kyle at 0600 UTC 21 September when it was about 680 n mi east of Bermuda. While making the loop, thunderstorms developed around the low-level center and Kyle gradually acquired warm-core tropical characteristics. It is estimated that Kyle became a tropical storm at 1800 UTC 22 September about 760 n mi east of Bermuda. Under the influence of weak steering currents, Tropical Storm Kyle drifted erratically toward the southwest for about a week and steadily intensified. Kyle became a hurricane at 1200 UTC 25 September about 550 n mi east-southeast of Bermuda. A peak intensity of 75 kt is estimated to have occurred at 1200 UTC 26 September about 425 n mi east-southeast of Bermuda. Kyle maintained this intensity for the next 24 hours before gradually weakening under the influence of moderate northwesterly to northerly vertical shear.

After Kyle weakened below tropical storm strength at 1800 UTC 30 September, the cyclone made a slow counter-clockwise loop about 300 n mi west of Bermuda from 5-8 October. Afterwards, Kyle moved westward and then northwestward before making landfall along the South Carolina coast late on 11 October. During this period, fluctuations in intensity occurred and Kyle strengthened back into a tropical storm on 1, 6, and 11 October.

After making its first landfall near McClellanville, South Carolina at around 1700 UTC 11

October, Tropical Storm Kyle moved northeastward and skirted the remaining upper coastline of South Carolina. Its center moved inland again a few hours later near Long Beach, North Carolina around 2200 UTC. Kyle weakened to a tropical depression by 0000 UTC 12 October near Surf City, North Carolina and then strengthened back into a tropical storm over Pamlico Sound six hours later. Shortly thereafter, it exited the eastern portion of the state near Nags Head at around 0800 UTC. The cyclone eventually merged with a cold front later that day at 1200 UTC, when it was located about 280 n mi south-southwest of Nantucket, Massachusetts.

Kyle lasted for 22 days making it the third longest-lived Atlantic tropical cyclone, after Ginger of 1971 and Inga of 1969.

b. Meteorological Statistics

Observations in Kyle (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 observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command.

Ship reports of tropical storm force winds associated with Kyle are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Kyle's peak intensity of 75 kt from 1200 UTC 26 September to 1200 UTC 27 September is based on a blend of subjective and 3-h objective Dvorak satellite intensity estimates. The minimum pressure of 980 mb at 0000 UTC 27 September is estimated based Dvorak satellite intensity estimates, and on the best appearance and definition of the eye in both visible and infrared satellite imagery. The 35-kt intensity at landfall along the South and North Carolina coasts was based on a blend of 1500 ft flight-level winds of 38 kt (reduced to 32 kt surface wind estimate) and offshore buoy reports of 10-minute average wind speeds of 35 kt with gusts to 40 kt. However, tropical storm force winds were confined to offshore waters in the eastern semicircle and there were no reports of sustained tropical storm force winds along or inland of the United States coast.

c. Casualty and Damage Statistics

As a result of the relatively weak sustained winds at landfall, Kyle caused no significant structural damage and only minor beach erosion was reported along the North Carolina and South Carolina coastlines. Storm surge values were generally around 1 ft from Florida to North Carolina, with a few isolated occurrences of near 2 ft at Fort Pulaski, Georgia and at Charleston Harbor, South Carolina.

Rainfall totals were generally less than 2 in with a few isolated amounts of 5-6 in reported. Minor urban flooding occurred.

At least 4 tornadoes were reported across eastern South Carolina and southeastern North Carolina during Kyle's passage. In South Carolina, an F2 tornado touched down in Georgetown, and tossed and severely damaged 5 mobile homes and a car. Twenty-five additional structures sustained at least minor damage. Eight people were injured.

In North Carolina, a damaging F1-F2 tornado touched down near Pantego, in Beaufort County. The tornado flipped one mobile home, blew the roof off of one house, and destroyed 7 hog houses on Benson Farms, which resulted in \$1.5-2.0 million in damage. Weaker tornadoes touched down in Belvoir and overturned two mobile homes and knocked a house off its foundation. Another weak tornado touched down east of Washington, North Carolina causing no damage. No injuries were reported with any of the North Carolina tornadoes.

The reported insured losses associated with Kyle were approximately \$2.5 million. Total damages is estimated at \$5.0 million.

No deaths were reported in association with Kyle.

d. Forecast and Warning Critique

Average official track errors (with the number of cases in parentheses) for Kyle were 33 (56), 59 (51), 96 (46), 131 (44), and 190 (45) 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 (Table 4). The GFDL model (not available at the forecast preparation time) was better than the official forecast (OFCL) at all times, especially at and beyond 36 h. The GUNS and GUNA ensemble models were also better than the OFCL at all times, and much better than the GFDL at 48 and 72 h.

Average official intensity errors were 4, 7, 9, 11, and 14 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. While the official intensity errors were lower than the 10-year average, there was a slight positive bias (over forecast). However, the official intensity errors were lower than the SHIPS, SHIFOR, GFDL, and GFDI intensity forecast model errors.

A total of 89 advisories were written on Kyle and the cyclone weakened below and then strengthened back to tropical storm or subtropical storm status on four separate occasions.

Table 5 lists the watches and warnings associated with Kyle.

Acknowledgments

Some of the data in this report was furnished by National Weather Service Forecast Offices in Jacksonville, FL, Charleston, SC, Wilmington, NC and Newport/Morehead City, NC.

Table 1. Best track for Hurricane Kyle, 20 September - 12 October 2002.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
20 / 1800	28.3	51.8	1007	25	subtropical depression
21 / 0000	29.3	51.4	1007	30	"
21 / 0600	30.4	51.6	1007	35	subtropical storm
21 / 1200	31.0	51.6	1007	35	"
21 / 1800	31.7	51.3	1006	40	"
22 / 0000	32.4	50.9	1004	45	"
22 / 0600	32.8	50.5	1006	40	"
22 / 1200	33.2	49.9	1006	40	"
22 / 1800	33.3	49.5	1006	40	"
23 / 0000	33.2	49.1	1007	35	tropical storm
23 / 0600	32.7	49.4	1007	35	"
23 / 1200	32.3	49.5	1005	35	"
23 / 1800	31.9	49.6	1003	40	"
24 / 0000	31.4	50.0	1003	40	"
24 / 0600	31.0	50.4	1000	45	"
24 / 1200	30.6	50.7	997	50	"
24 / 1800	30.3	51.1	994	55	"
25 / 0000	30.0	52.1	994	55	"
25 / 0600	29.7	53.7	994	55	"
25 / 1200	29.3	54.4	990	60	"
25 / 1800	29.0	55.3	987	65	hurricane
26 / 0000	28.6	56.6	987	65	"
26 / 0600	28.2	57.5	984	70	"
26 / 1200	27.9	58.3	982	75	"
26 / 1800	27.8	59.0	981	75	"

27 / 0000	27.5	59.5	980	75	"
27 / 0600	27.1	60.0	982	75	"
27 / 1200	27.0	60.4	982	75	"
27 / 1800	26.8	60.8	984	70	"
28 / 0000	26.5	61.4	984	70	"
28 / 0600	26.3	62.3	987	65	"
28 / 1200	26.5	62.9	990	60	tropical storm
28 / 1800	26.7	63.2	997	50	"
29 / 0000	27.1	63.7	1000	45	"
29 / 0600	27.2	64.4	1002	40	"
29 / 1200	27.7	64.7	1002	40	"
29 / 1800	28.1	64.7	1002	40	"
30 / 0000	28.7	64.6	1002	40	"
30 / 0600	29.1	64.7	1003	35	"
30 / 1200	29.0	65.5	1004	35	"
30 / 1800	27.8	66.7	1005	30	tropical depression
01 / 0000	28.2	66.8	1005	30	"
01 / 0600	28.5	66.8	1008	30	"
01 / 1200	28.5	67.2	1005	35	tropical storm
01 / 1800	28.5	67.5	1002	40	"
02 / 0000	28.4	67.7	1000	45	"
02 / 0600	28.5	67.8	1000	45	"
02 / 1200	28.8	67.6	997	50	"
02 / 1800	29.0	66.9	994	55	"
03 / 0000	29.1	66.7	994	55	"
03 / 0600	29.0	66.6	994	55	"

03 / 1200	29.0	67.2	1000	50	"
03 / 1800	29.3	67.7	1000	45	"
04 / 0000	29.4	68.0	1000	45	"
04 / 0600	29.6	68.4	1000	35	"
04 / 1200	30.1	69.5	1004	35	"
04 / 1800	30.6	70.2	1004	35	"
05 / 0000	31.1	70.9	1004	35	"
05 / 0600	31.6	71.6	1006	30	tropical depression
05 / 1200	32.3	71.3	1005	30	"
05 / 1800	32.9	70.8	1005	30	"
06 / 0000	33.2	70.1	1006	30	"
06 / 0600	33.6	69.7	1008	30	"
06 / 1200	33.3	69.7	1007	35	tropical storm
06 / 1800	32.8	69.7	1006	35	"
07 / 0000	32.6	69.7	1006	35	"
07 / 0600	32.6	70.4	1006	35	"
07 / 1200	32.6	70.8	1006	35	"
07 / 1800	32.7	70.9	1006	35	"
08 / 0000	32.6	71.0	1006	35	"
08 / 0600	32.1	71.2	1006	35	"
08 / 1200	31.4	71.3	1006	35	"
08 / 1800	30.7	71.9	1009	30	tropical depression
09 / 0000	29.8	72.4	1010	30	"
09 / 0600	29.0	73.3	1009	30	"
09 / 1200	28.7	74.0	1010	30	"
09 / 1800	28.5	74.8	1011	25	"
10 / 0000	28.4	75.8	1010	25	"

10 / 0600	28.3	77.0	1010	25	"
10 / 1200	28.4	78.1	1010	25	"
10 / 1800	28.9	79.5	1010	30	"
11 / 0000	29.8	80.2	1009	30	"
11 / 0600	30.7	80.8	1008	35	tropical storm
11 / 1200	31.8	80.7	1008	35	"
11 / 1800	33.2	79.3	1011	35	"
12 / 0000	34.2	78.0	1012	30	tropical depression
12 / 0600	35.4	75.9	1009	40	tropical storm
12 / 1200	36.7	74.1	1009	40	"
12 / 1800					merged with a cold front
27 / 0000	27.5	59.5	980	75	minimum pressure
11 / 1700	33.0	79.5	1011	35	1 st landfall near McClellanville, SC
11 / 2200	33.9	78.4	1011	35	2 nd landfall near Long Beach, NC

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Kyle, 20 September - 12 October 2002. (Note: M = missing data)

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
25 / 0900	LATU5	33.5	55.6	030 / 40	1019.6
26 / 0600	C6LP4	25.1	58.2	230 / 36	1008.0
26 / 1800	C6LP4	23.9	61.5	270 / 35	1009.5
29 / 0000	ELGJ9	23.5	65.4	270 / 37	1011.0
29 / 0300	ELGJ9	23.3	66.2	270 / 37	1011.5
30 / 1500	ELZA8	33.5	65.0	050 / 42	1017.2
02 / 0000	KGXA	26.9	66.5	M / 35	1010.0
12 / 1200	SGAK	37.1	74.1	090 / 35	1012.5
12 / 1200	LMWR3	39.9	68.7	090 / 41	1020.4

Table 3. Selected surface observations for Hurricane Kyle, 20 September - 12 October 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)			
Florida								
Fernandina Beach						1.31		2.05
Jacksonville Beach								1.19
Mayport						1.17		
St. Augustine (KSGJ)	10/2355	1013.3	10/1615	17	28			
Georgia								
Brunswick								0.84
Eden								1.10
Fort Pulaski						2.1		
Hunter Field (KSVN)								5.35
Saint Simons Island						1.07		
Savannah (RAWS)								3.30
Savannah (KSAV)	11/1102	1012.5						2.25
Woodbine								0.85
North Carolina								
Bald Head Island			11/2130		43	0.5		
Carolina Beach			11/2145		42	0.5		
Cherry Point (KNKT)								1.02
Frisco (KHSE)	12/0200	1010.8	12/0200		32			2.84
Greenville (PGVN7)								5.60
Holden Beach			11/2100		37	0.5		
Lumberton								2.00
Manteo (KMQI)								1.23
Oak Island			11/2100		38			
WFO Newport (KMHX)								2.99
WFO Wilmington	11/1913	1012.2						
Washington (KOCW)								1.99
Williamson								5.30
Williamson 2E								4.73
South Carolina								
Beaufort								2.65
Charleston (KCHS)	11/1540	1011.1	11/1434	20	25			4.91
Charleston City Office			11/1400		34			1.65
Charleston Harbor						1.9		

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)			
Edisto Beach								6.35
Georgetown Coast Guard	11/1800	1009.1	11/1720		43			1.82
Jamestown								1.78
Myrtle Beach (KMYR)	11/1900	1011.2						
N. Myrtle Beach (KCRE)	11/1913	1011.2						1.10
Walterboro								3.00
Wambam (RAWS)								1.67
Witherbee (RAWS)								5.85

NOAA National Data Buoy Center buoys

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)			
41004 (32.5N 79.1W)			11/1400		34			
41536 (21.8N 67.7W)	29/0600	1014.5	29/0600	51				
41652 (28.7N 65.8W)	30/0320	1007.7	30/0320	45				
41652 (28.6N 65.6W)	01/1420	1013.4						
41652 (28.6N 65.6W)	01/1620	1014.4	01/1620	43				
41652 (28.6N 65.6W)	01/1720	1012.8	01/1620	35				
41652 (28.6N 65.6W)	02/0320	1013.3	02/0320	41				
41652 (28.6N 65.6W)	02/0420	1013.0	02/0420	43				
41652 (28.6N 65.6W)	02/0520	1012.6	02/0520	41				
41652 (28.6N 65.6W)	02/0920	1011.0	02/0920	35				
41652 (28.6N 65.6W)	02/1120	1011.7	02/0920	35				
41652 (28.6N 65.6W)	02/1220	1011.6	02/1220	41				
41652 (28.6N 65.6W)	02/1720	1009.8	02/1720	43				
41652 (28.6N 65.6W)	02/1820	1007.8	02/1820	37				
41652 (28.6N 65.4W)	03/0220	1009.0	03/0220	35				
41652 (28.6N 65.4W)	03/0320	1009.4	03/0720	39				
41652 (28.6N 65.4W)	03/0520	1008.4	03/0820	39				
41652 (28.6N 65.4W)	03/0620	1008.1	03/0620	41				
41652 (28.6N 65.4W)	03/0720	1007.3	03/0720	43				
41652 (28.6N 65.4W)	03/0820	1007.5	03/0820	35				
41652 (28.6N 65.4W)	03/1120	1010.0	03/1120	37				

NOAA National Data Buoy Center C-MAN stations

FBIS1 (32.7N 79.9W)			11/0307		34			
FPSN7 (33.5N 77.6W)			11/1700	35	38			
FPSN7 (33.5N 77.6W)	11/2100	1012.0	11/2100	35 ^e	40			
DSL7N (35.2N 75.3W)			11/2210	41 ^e	51			
DSL7N (35.2N 75.3W)	12/0300	1010.5	12/0500	40	43			
DSL7N (35.2N 75.3W)			12/0500	36				
DSL7N (35.2N 75.3W)	12/0700	1010.6	12/0700	38				
CLKN7 (34.6N 76.5W)	11/2300	1011.5						
ALSN6 (40.5N 73.8W)			12/1300	36				

^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.

Table 4. Preliminary forecast evaluation (heterogeneous sample) for Hurricane Kyle, 20 September - 12 October 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	47 (58)	98 (53)	169 (48)	248 (46)	442 (47)
GFDI	28 (52)	54 (47)	98 (42)	133 (40)	194 (41)
GFDL	31 (58)	49 (53)	77 (48)	111 (46)	172 (47)
LBAR	41 (57)	72 (52)	112 (47)	169 (45)	287 (46)
AVNI	41 (52)	82 (47)	138 (42)	185 (39)	283 (39)
AVNO	40 (58)	69 (52)	115 (48)	149 (45)	234 (45)
AEMI	40 (40)	82 (36)	133 (33)	190 (32)	283 (32)
BAMD	48 (57)	98 (52)	163 (47)	224 (45)	307 (46)
BAMM	39 (57)	74 (52)	121 (47)	165 (45)	229 (46)
BAMS	50 (57)	92 (52)	129 (47)	148 (45)	182 (46)
NGPI	38 (52)	68 (47)	103 (42)	121 (40)	196 (41)
NGPS	37 (51)	58 (46)	85 (41)	118 (39)	173 (40)
UKMI	41 (51)	74 (46)	131 (41)	109 (35)	189 (34)
UKMO	37 (29)	69 (28)	118 (26)	130 (22)	167 (21)
A98E	45 (57)	79 (52)	124 (47)	180 (45)	344 (46)
A9UK	43 (27)	80 (27)	101 (25)	137 (24)	273 (24)
GUNS	30 (51)	55 (46)	95 (41)	102 (35)	158 (34)
GUNA	30 (51)	53 (46)	94 (41)	105 (34)	175 (32)
OFCL (Official)	33 (56)	59 (51)	96 (46)	131 (44)	190 (45)
NHC Official (1992-2001 mean)	43 (2199)	81 (1965)	115 (1759)	148 (1580)	222 (1272)

Table 5. Watch and warning summary for Hurricane Kyle, 20 September - 12 October 2002.

Date/Time (UTC)	Action	Location
30 / 1500	Tropical Storm Watch Issued	Bermuda
01 / 2100	Tropical Storm Watch Discontinued	Bermuda
10 / 1500	Tropical Storm Watch Issued	Cocoa Beach, FL to Brunswick, GA
10 / 2100	Tropical Storm Watch Extended Northward	Flagler Beach, FL to Edisto Beach SC
11 / 0300	Tropical Storm Warning Issued	North of Brunswick, GA to Cape Fear, NC
11 / 0300	Tropical Storm Watch Discontinued	From Brunswick, GA southward
11 / 0900	Tropical Storm Warning In Effect	From north of Brunswick, GA northward to Surf City, NC
11 / 1200	Tropical Storm Warning Discontinued	Along the Georgia coast
11 / 1200	Tropical Storm Warning In Effect	North of Savannah River to Surf City, NC
11 / 1500	Tropical Storm Warning Extended Northeastward	North of Savannah River to Currituck Beach Light, NC, including the Pamlico Sound
11 / 2100	Tropical Storm Warning Discontinued	South of Little River Inlet, SC
11 / 2100	Tropical Storm Warning In Effect	North of Little River Inlet, SC to Currituck Beach Light, NC, including the Pamlico Sound
12 / 0000	All Tropical Storm Warnings Discontinued	

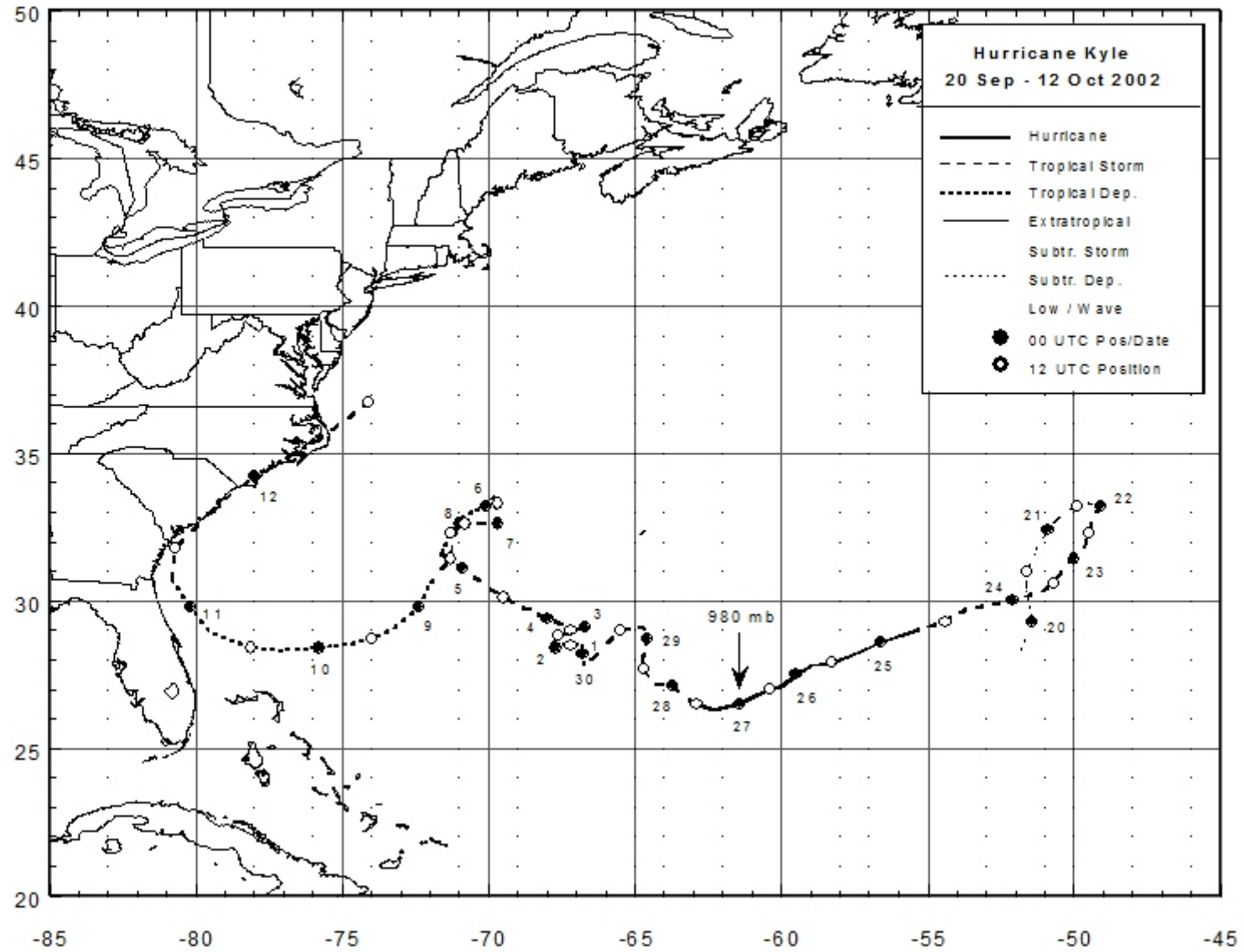


Figure 1. Best track positions for Hurricane Kyle, 20 September - 12 October 2002, with minimum central pressure.

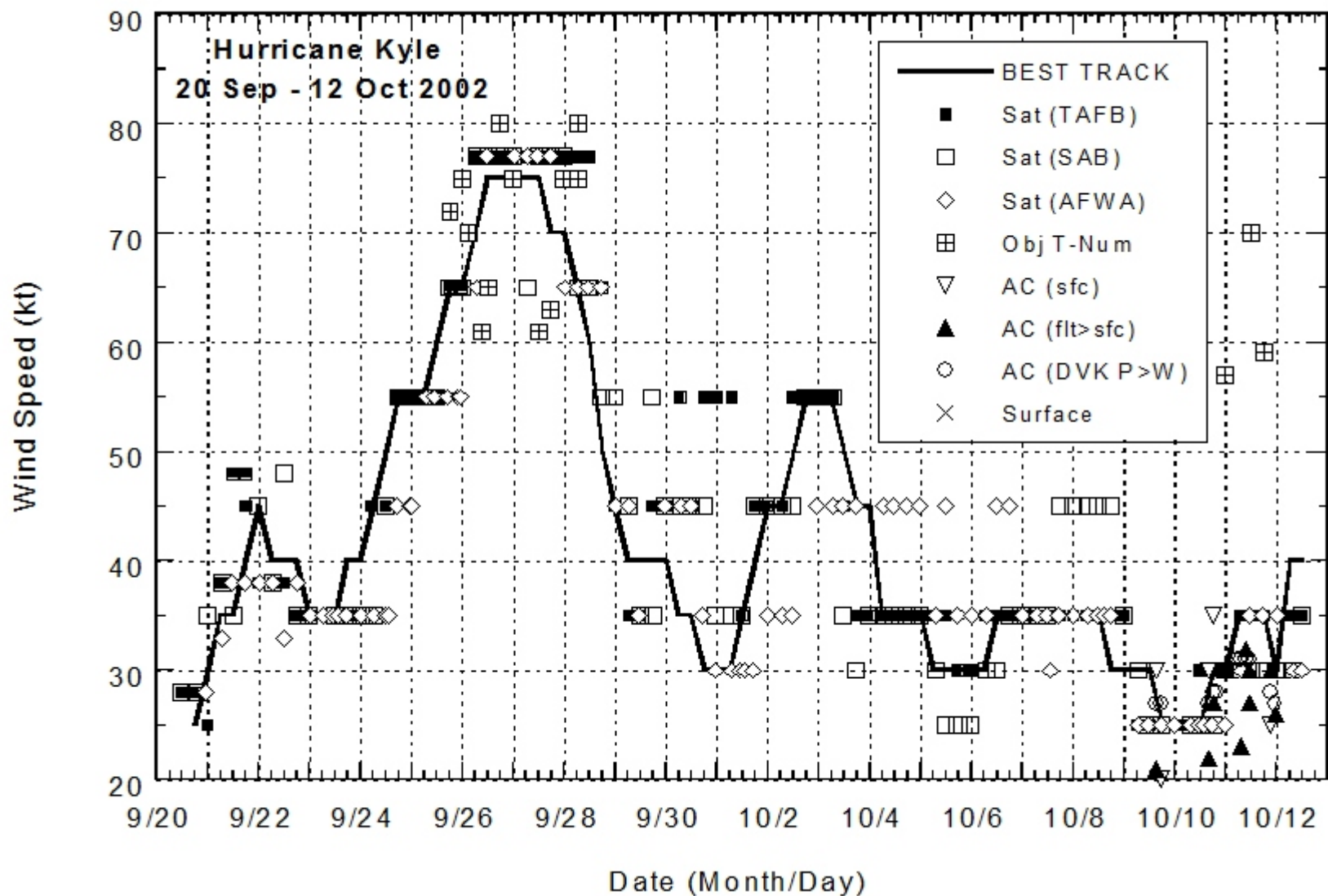


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Kyle, 20 September - 12 October 2002. Aircraft observations have been adjusted for elevation using 75% and 80% reduction factors for observations from 925 mb and 1500 ft, respectively. Objective Dvorak estimates are 3-h linear averages.

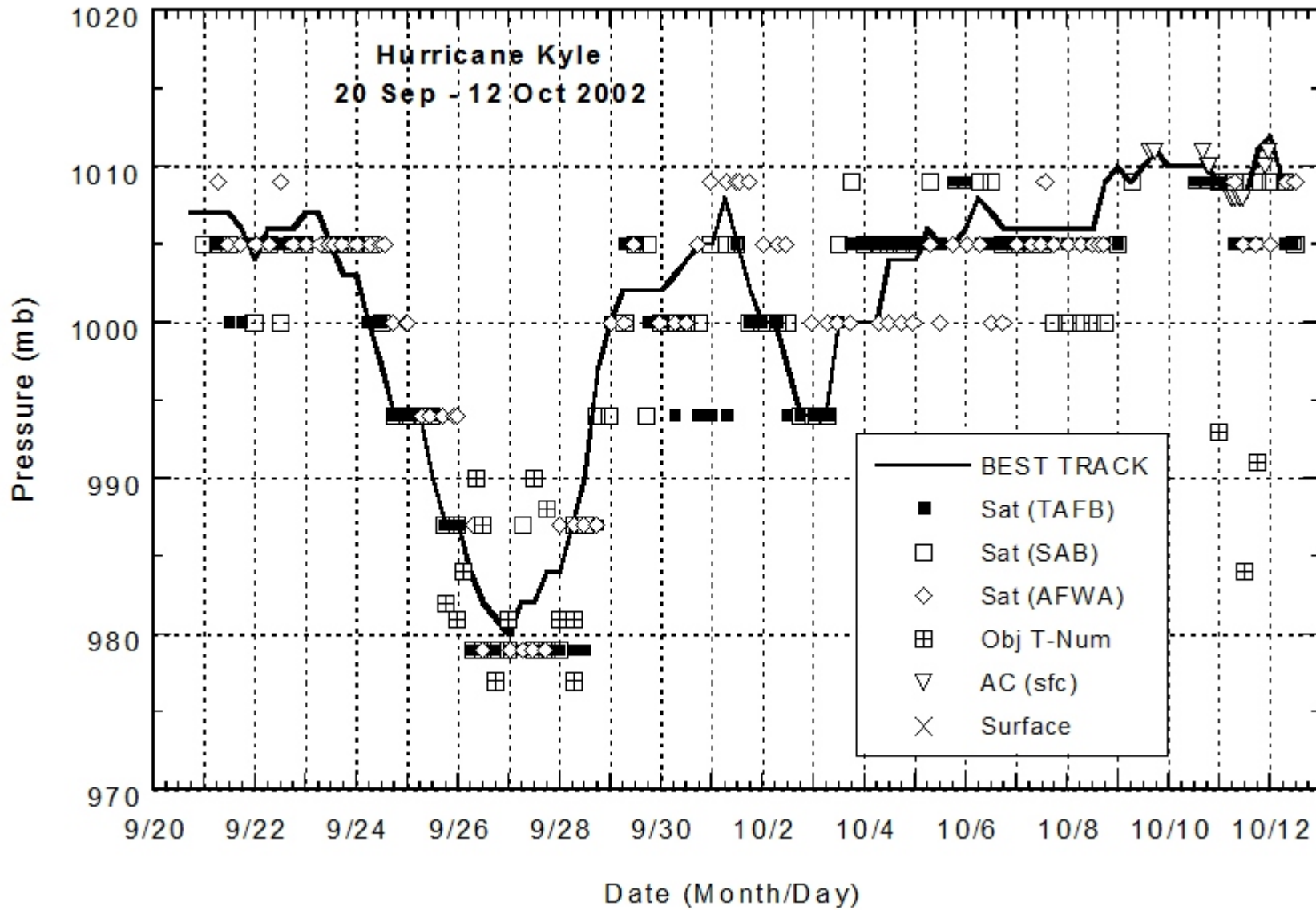


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Kyle, 20 September - 12 October 2002. Objective Dvorak estimates are 3-h linear averages.