NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM KIRK

(AL122018)

22–28 September 2018

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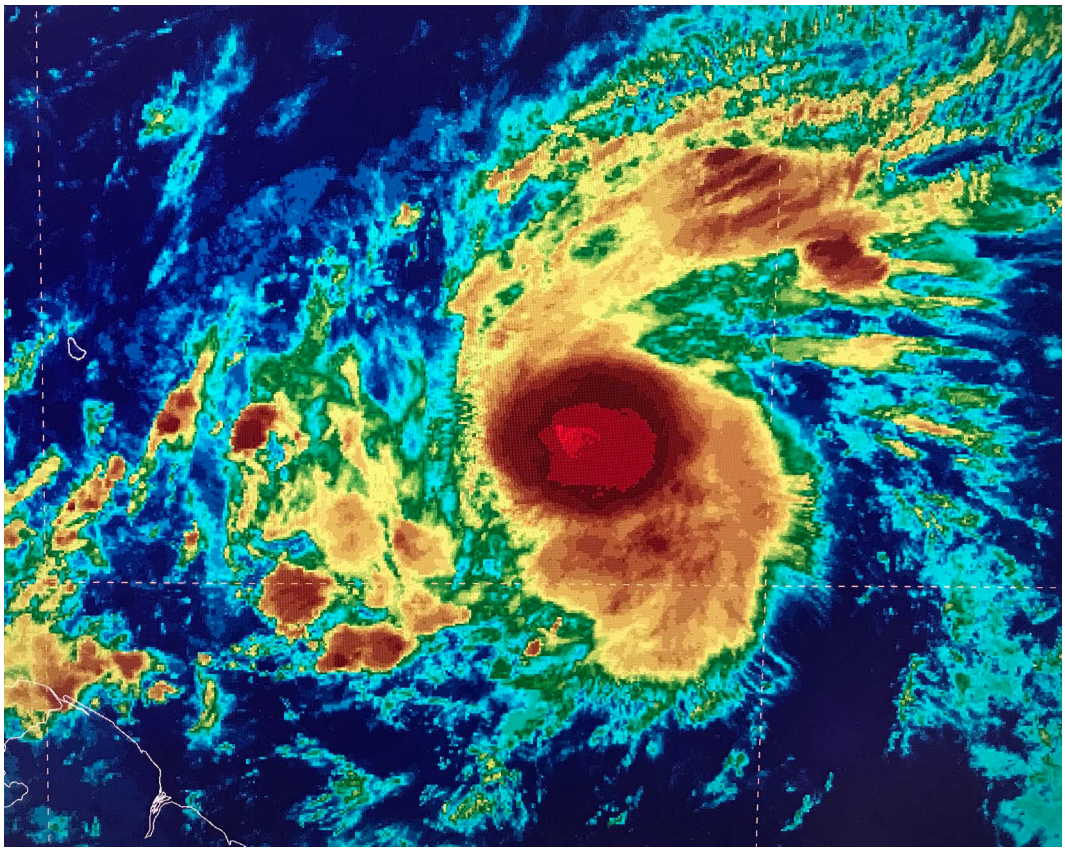

GOES-16 INFRARED IMAGE OF KIRK NEAR PEAK INTENSITY AT 1200 UTC 26 SEPTEMBER.

Kirk formed in the eastern tropical Atlantic at an unusually low latitude before opening up into a tropical wave only a day later. Eventually the wave reformed into a tropical cyclone and made landfall on St. Lucia as a moderately strong tropical storm before dissipating over the eastern Caribbean Sea.

Tropical Storm Kirk

22–28 SEPTEMBER 2018

SYNOPTIC HISTORY

The low-latitude wave that spawned Kirk departed west Africa late on 20 September, accompanied by a large area of thunderstorms and a broad area of low pressure. Convection diminished somewhat by the afternoon of 21 September, but re-fired overnight near the low. A well-defined center formed around 0600 UTC 22 September, marking the formation of a tropical depression about 450 n mi south-southeast of the Cabo Verde Islands. Scatterometer data indicate that the cyclone became a tropical storm 6 h later. The "best track" chart of Kirk'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].

Initially Kirk was moving toward the west-northwest, but as the subtropical ridge strengthened and expanded westward, the storm moved faster toward the west. In addition, a large band of convection formed and propagated slowly away from the center, somewhat akin to an outflow boundary, indicating the presence of dry mid-level air. These factors caused Kirk to lose its closed surface circulation and degenerate into a tropical wave by 1200 UTC 23 September, only 30 h after it initially became a tropical cyclone. The wave continued moving quickly westward during the next couple of days while producing abundant convection along the way. On 25 September, the forward speed of the system slowed and thunderstorm activity become more concentrated near the center, leading to the re-formation of Kirk near 0000 UTC 26 September about 450 n mi east-southeast of Barbados. Scatterometer data around that time showed that the maximum winds of the cyclone had increased to about 45 kt.

Further strengthening occurred overnight, and Kirk reached its peak intensity of 55 kt 12 h after its re-formation and turned toward the west-northwest. The storm maintained an intensity of 50 kt on 27 September despite increasing westerly shear, which caused the center to become exposed at times. The center of Kirk passed about 35 n mi north of Barbados that day, with all of its associated thunderstorm activity located in the eastern semicircle of the cyclone due to the shear. Late on 27 September, Kirk turned west-southwestward, largely due to the storm coming under the influence of the southeastern portion of the western Atlantic ridge, the decoupling of the low- and mid-level centers and the influence of the mountains of the eastern Caribbean islands. The storm made landfall on St. Lucia near 0030 UTC 28 September with 45-kt winds and a minimum central pressure of 1002 mb. After entering the eastern Caribbean, Kirk resumed a west-northwestward course and continued to weaken due to the shear. Aircraft reconnaissance was unable to find a closed circulation later that day, and Kirk degenerated into

[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.

a tropical wave again near 0000 UTC 29 September while it was located a few hundred miles south of the Virgin Islands.

METEOROLOGICAL STATISTICS

Observations in Kirk (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB), and the objective Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) estimates from CIMSS at the University of Wisconsin. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from six flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Global Precipitation Mission (GPM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track.

The estimated peak intensity of 55 kt at 1200 UTC 26 September is based on scatterometer data and a TAFB Dvorak fix a few hours before reconnaissance arrived. The peak reconnaissance 850-mb flight-level winds were 63 kt at 1259 UTC 27 September, with SFMR maxima near 52 kt. The lowest central pressure of 998 mb was noted twice during Kirk's lifetime, and was based on an analysis of dropsonde data from the reconnaissance planes.

Surface observations from Kirk are given in Table 2. Two stations on St. Lucia reported sustained winds of 40 kt (10-min average), which support the 45-kt intensity at landfall on that island. Barbados and Martinique also reported sustained tropical-storm-force winds.

Kirk became a tropical storm at a low latitude, only 8.1°N, in the tropical Atlantic Ocean. It is the second lowest-latitude tropical storm to form in the basin, only eclipsed by the 3rd tropical storm of 1902, which formed at 7.7°N.

CASUALTY AND DAMAGE STATISTICS

There were no deaths reported in association with Kirk. Very heavy rains (in excess of 10 inches) caused severe street flooding and power outages in Barbados, with several people rescued from floods on that island. However, no estimates of damage are available.

FORECAST AND WARNING CRITIQUE

The genesis forecasts for Kirk (Tables 3a, 3b) were poor for both the initial genesis and its re-formation. The system was introduced into the Tropical Weather Outlook only 36 h before

genesis occurred with a low (<40% chance) of genesis within 5 days, and reached the medium (40–60%) category 6 h later. For the 2-day predictions, the system was given a low chance 30 h before it formed, with a medium probability 6 h before genesis. However, none of the NHC forecasts reached the high category (>60% chance). The re-formation of Kirk was given a 50/50 chance of occurring within 48 h only 30 h before genesis occurred, but did not reach the high category either. Upper-level winds were forecast to be only marginally conducive near the Lesser Antilles so the probabilities were not raised to the high category. This type of challenging genesis forecast is not unusual for systems forming in marginal environments.

A verification of NHC official track forecasts for Kirk is given in Table 4a. Official forecast track errors were higher than the 5-yr mean official errors at all time periods through 48 h, then below the 5-yr mean errors afterward. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. The official forecast (OFCL) was consistently better than the bulk of the model guidance, albeit in a limited sample at long range. The ECMWF (EMXI) did not have a particularly good performance for this storm through 48 h, while the NOAA corrected-consensus aid (HCCA) was the best of the consensus models for Kirk.

A verification of NHC official intensity forecasts for Kirk is given in Table 5a. Official intensity forecast errors were below the mean official errors for the previous 5-yr period at all forecast times, with the errors about half of the long-term mean or less after 12 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. Even though NHC's intensity forecasts had a great performance for this storm, most of the consensus guidance were even better, with remarkably low errors beyond 12 h, with the caveat of a small sample size. Notably the statistical-dynamical consensus DSHP and, to a lesser extent, LGEM did quite poorly for Kirk, with a distinct high bias at long range. The IVDR model (which double-weights the regional hurricane models over LGEM/DSHP) was consequently one of the best consensus models.

Watches or warnings required for Kirk are given in Table 6.

Table 1. Best track for Tropical Storm Kirk, 22–28 September 2018.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 0600	7.7	21.8	1007	30	tropical depression
22 / 1200	8.1	22.9	1005	35	tropical storm
22 / 1800	8.5	24.1	1005	35	"
23 / 0000	8.9	25.7	1005	35	"
23 / 0600	9.1	27.3	1005	35	"
23 / 1200	9.2	29.3	1005	35	tropical wave
23 / 1800	9.3	31.7	1006	30	"
24 / 0000	9.4	34.1	1007	25	"
24 / 0600	9.6	36.4	1007	30	"
24 / 1200	9.8	38.5	1007	35	"
24 / 1800	10.0	40.6	1007	35	"
25 / 0000	10.3	42.7	1007	35	"
25 / 0600	10.7	44.8	1007	35	"
25 / 1200	11.0	46.8	1007	35	"
25 / 1800	11.3	48.6	1006	40	"
26 / 0000	11.5	50.3	1005	45	tropical storm
26 / 0600	11.8	52.0	1004	50	"
26 / 1200	12.1	53.6	1002	55	"
26 / 1800	12.5	55.0	998	55	"
27 / 0000	12.9	56.4	1002	50	"
27 / 0600	13.3	57.7	1002	50	"
27 / 1200	13.6	58.7	998	50	"
27 / 1800	14.0	59.8	1000	50	"
28 / 0000	13.8	60.8	1002	45	"
28 / 0030	13.8	60.9	1002	45	"

28 / 0600	13.3	61.9	1005	45	"
28 / 1200	13.6	63.1	1007	40	"
28 / 1800	14.4	64.2	1007	35	"
29 / 0000					dissipated
26 / 1800	12.5	55.0	998	55	minimum pressure and maximum winds
28 / 0030	13.8	60.9	1002	45	landfall on St. Lucia

Table 2. Selected surface observations for Tropical Storm Kirk, 22–28 September 2018.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)	Storm tide (ft)	Estimated Inundation (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Barbados									
Grantley Adams Airport (TBPB)	1006.3	27/1900	28/0315	35	40				10.07
St. Lucia									
Hewanorra Airport (TLPL)	1005.3	28/0000	28/0135	40[l]	52				1.10
George F.L. Charles Airport (TLPC)	1005.5	28/0000	28/0020	40	54				1.12
St. Martin									
Grand-Case Airport (TFFG)	1012.9	28/0300	28/1356	20	37				0.48
Martinique									
Lamentin Airport (TFFF)	1008.4	27/2000	28/0027	26	41				0.89
Trinite	1008.9	27/2000	28/0244	36 (26 m ASL)	50				
St-Anne			28/0107	24 (22 m ASL)	44				
Fond-Denis-Cadet			28/0051	28 (493 m ASL)	60				
Diamant			28/0057	26 (366 m ASL)	46				
Vauclin			28/0343	36 (12 m ASL)	50				
Lorrain			28/0042	21 (83 m ASL)	38				
Fort-de-France			28/0039	18 (143 m ASL)	41				

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Sustained wind averaging periods are 10 min unless otherwise noted.
[l] Incomplete data.

Table 3a. Number of hours in advance of the initial formation of Kirk associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	30	36
Medium (40%-60%)	6	30
High (>60%)	-	-

Table 3b. Number of hours in advance of the re-formation of Kirk associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis, and operationally Kirk was only a wave for 48 hours before re-formation.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	30	30
Medium (40%-60%)	30	30
High (>60%)	-	-

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Kirk. Mean errors for the previous 5-yr period 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	29.2	45.9	67.7	93.3	**75.8**	**88.0**	**57.0**
OCD5	38.4	65.2	89.3	106.4	512.3	567.5	539.5
Forecasts	11	7	5	3	2	4	4
OFCL (2013-17)	24.1	37.4	50.5	66.6	98.4	137.4	180.7
OCD5 (2013-17)	44.7	95.8	153.2	211.2	318.7	416.2	490.6

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Kirk. 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	26.9	45.9	67.7	93.3	75.8	92.4	53.7
OCD5	34.3	65.2	89.3	106.4	512.3	572.7	550.0
GFSI	34.0	59.0	77.1	100.3	94.1	127.3	95.4
HMNI	36.8	76.8	105.3	156.5	177.1	220.7	256.0
HWFI	35.3	55.4	94.5	134.5	110.7	188.6	278.0
EGRI	38.0	54.9	**61.0**	**75.6**	327.3	429.4	584.6
EMXI	33.9	65.0	104.7	134.8	**60.9**	98.2	55.6
CMCI	39.4	74.6	104.2	133.6	241.8	330.6	506.7
AEMI	31.9	53.5	69.5	**83.7**	120.9	170.5	249.5
HCCA	26.9	**44.9**	68.2	100.9	**74.0**	108.0	82.0
FSSE	35.8	58.3	77.8	94.1	120.2	118.5	86.6
TVCA	28.7	49.8	69.5	98.9	120.2	167.8	202.0
TVCX	28.6	48.4	71.7	102.8	101.9	148.0	168.7
GFEX	29.8	53.5	81.8	112.8	**68.1**	104.4	**48.1**
TABD	57.7	155.2	259.8	365.7	339.2	538.6	920.9
TABM	32.3	69.1	108.1	148.0	147.8	118.9	178.8
TABS	58.0	117.5	150.1	181.3	**40.6**	93.2	88.5
Forecasts	9	7	5	3	2	3	3

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Kirk. Mean errors for the previous 5-yr period 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	**4.5**	**4.3**	**4.0**	**3.3**	**5.0**	**7.5**	**7.5**
OCD5	5.9	8.3	16.2	25.7	8.5	11.2	11.2
Forecasts	11	7	5	3	2	4	4
OFCL (2013-17)	5.5	8.0	10.1	11.4	12.7	14.5	15.0
OCD5 (2013-17)	7.1	11.1	14.4	17.4	20.6	22.3	23.7

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Kirk. 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	4.5	4.3	4.0	3.3	5.0	8.3	8.3
OCD5	6.1	8.3	16.2	25.7	8.5	12.7	13.7
GFSI	**4.4**	5.9	6.2	5.0	15.0	19.7	19.0
EMXI	5.1	5.7	5.2	5.3	17.5	24.3	22.0
DSHP	6.4	7.6	8.6	6.3	17.5	17.3	22.0
LGEM	6.1	5.3	4.8	5.0	16.5	25.3	26.3
HCCA	6.1	5.7	5.2	**3.0**	**2.5**	**6.0**	**2.0**
FSSE	5.9	**4.1**	**2.0**	3.7	**4.0**	**1.0**	**1.7**
IVCN	5.7	4.3	**2.4**	3.7	**3.0**	**4.0**	**7.7**
IVDR	5.6	**4.0**	**2.4**	4.0	**2.0**	**3.7**	**4.0**
HWFI	5.7	4.3	**2.0**	3.3	13.0	8.3	12.7
HMNI	7.0	6.6	6.0	9.0	11.0	15.0	**4.3**
Forecasts	10	7	5	3	2	3	3

Table 6. Watch and warning summary for Kirk, 22–28 September 2018.

Date/Time (UTC)	Action	Location
26 / 0900	Tropical Storm Watch issued	St. Vincent and the Grenadines
26 / 0900	Tropical Storm Warning issued	Barbados, St. Lucia
26 / 1200	Tropical Storm Warning issued	Dominica, Martinique, Guadeloupe
28 / 1200	Tropical Storm Warning discontinued	All
28 / 1500	Tropical Storm Watch discontinued	All

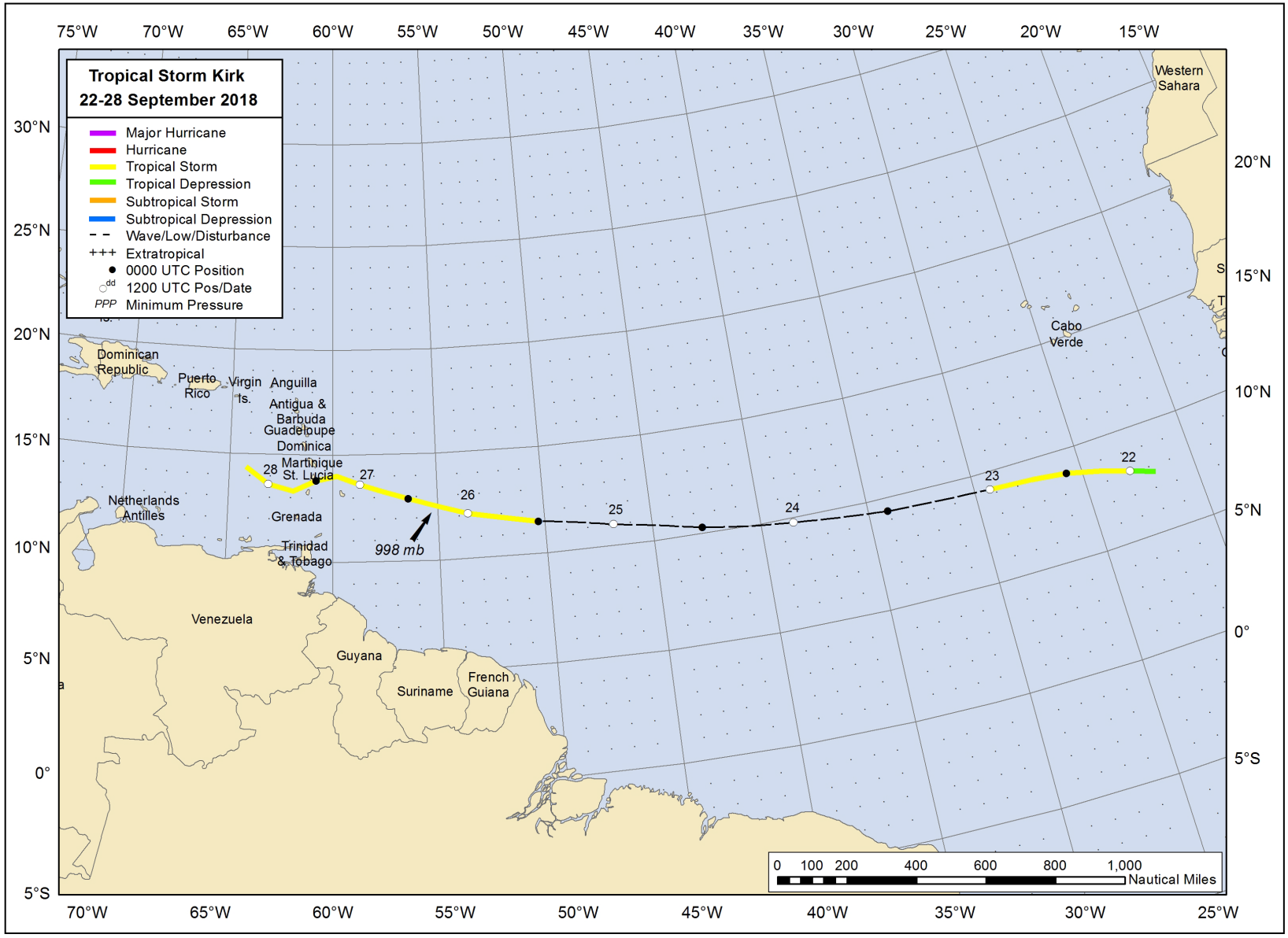

Figure 1. Best track positions for Tropical Storm Kirk, 22–28 September 2018.

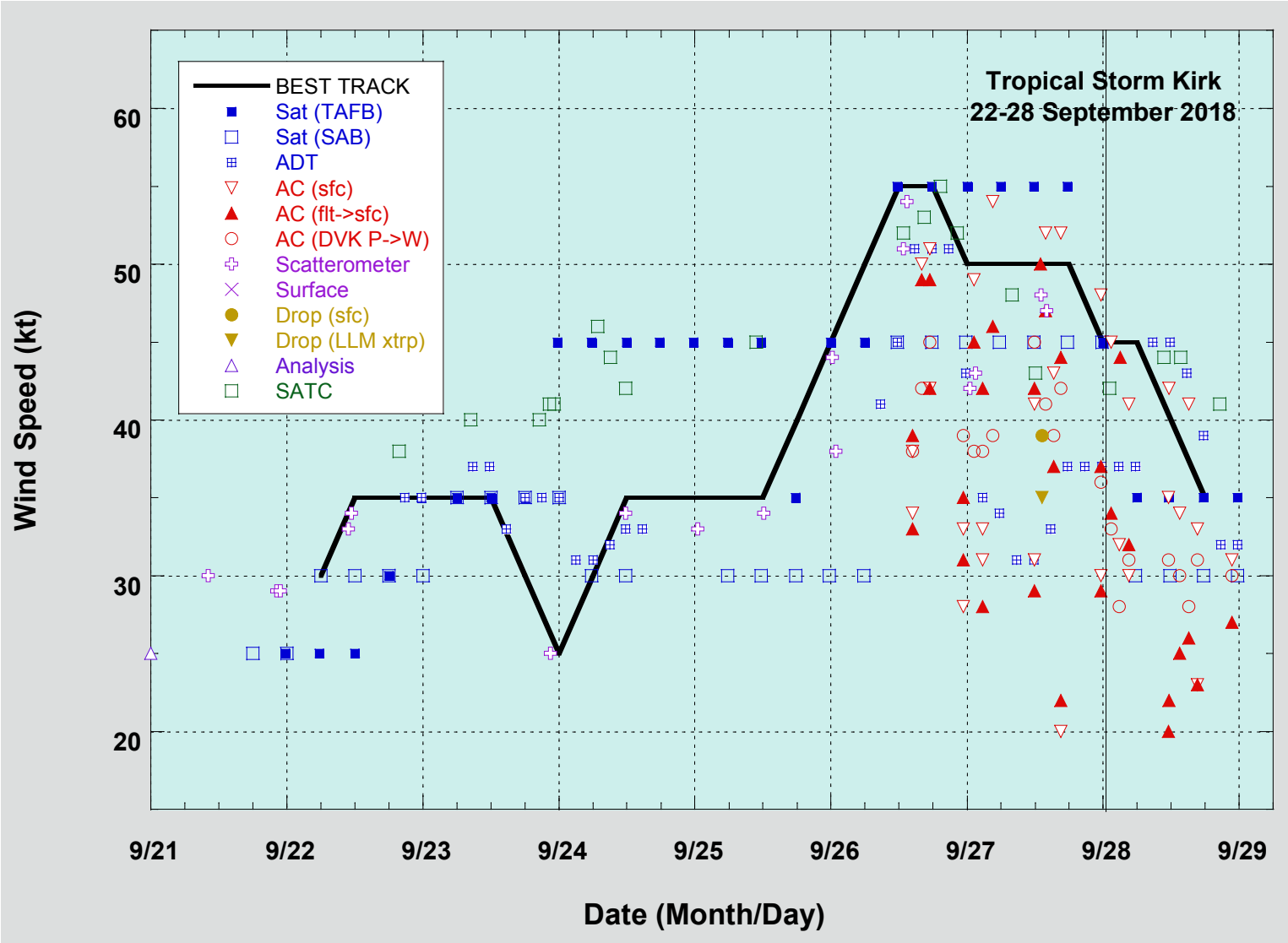

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Kirk, 22–28 September 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATC intensity estimates are the satellite consensus estimates from the Cooperative Institute for Meteorological Satellite Studies. Solid vertical line corresponds to landfall.

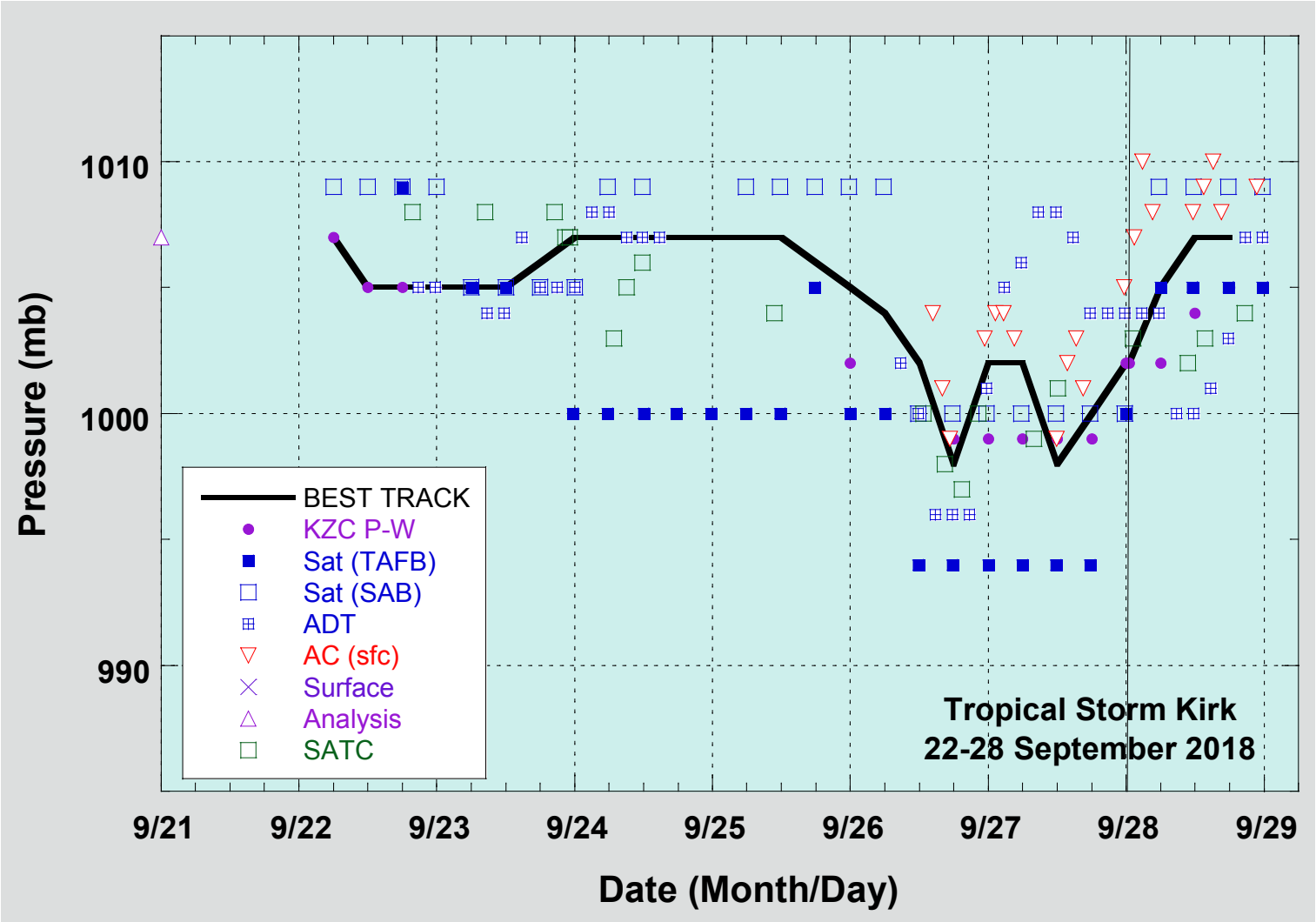

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Kirk, 22–28 September 2018. Advanced Dvorak Technique estimates represent the pressure from the Current Intensity at the nominal observation time. SATC pressures estimates are the satellite consensus estimates from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Solid vertical line corresponds to landfall.