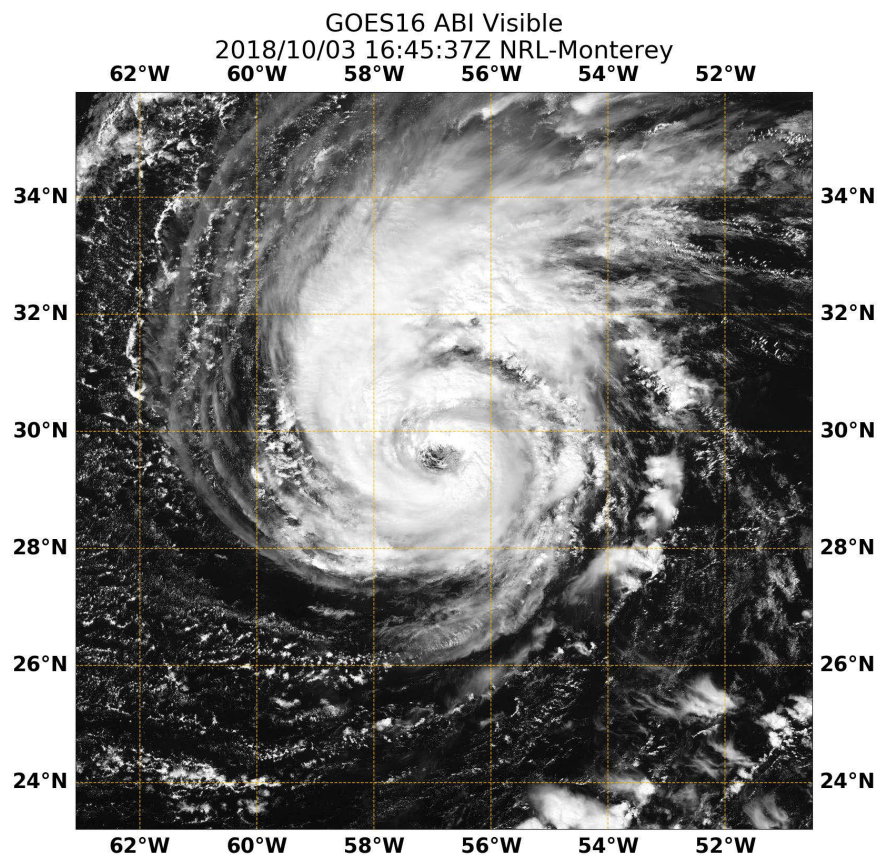# NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE LESLIE
(AL132018)
23 September–13 October 2018

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National Hurricane Center
29 March 2019

GOES16 ABI Visible
2018/10/03 16:45:37Z NRL-Monterey

GOES-16 VISIBLE IMAGE OF HURRICANE LESLIE AT 1645 UTC 3 OCTOBER 2018. IMAGE COURTESY OF NAVAL RESEARCH LABORATORY.

Leslie wandered across the subtropical Atlantic for about 3 weeks before finally hitting Portugal as an extratropical cyclone.

Hurricane Leslie

23 SEPTEMBER–13 OCTOBER 2018

SYNOPTIC HISTORY

Leslie originated from a non-tropical weather system. An extratropical low formed on a frontal boundary early on 22 September about 700 n mi west-southwest of the westernmost Azores. The low soon began to produce gale-force winds while moving slowly and erratically, and on 23 September, the cyclone lost frontal features and its outer curved cloud bands became sufficiently well-defined for the system to be designated as a subtropical storm. The "best track" chart of the 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[1]. Leslie continued to meander in a region of weak steering currents, and early on 25 September the cyclone weakened to a subtropical depression while embedded in an environment of dry air and moderate vertical shear,. Later that day, Leslie merged with a frontal zone and the system reverted back to extratropical cyclone status. While moving along a partial counterclockwise loop at an increased forward speed, the cyclone strengthened, likely due to baroclinic processes, and by early on 27 September it was producing hurricane-force winds. A gradual weakening trend commenced later that day. Although the intensity of the system decreased slightly on 28 September, curved bands of convection became better organized around the center of the cyclone, and Leslie re-acquired subtropical storm status by 1200 UTC that day. Over the next couple of days, Leslie's intensity changed little while the storm moved generally west-southwestward to southwestward, on the western side of a large deep-layer cyclonic circulation. Around 1800 UTC on 29 September, deep convection formed close enough to Leslie's center for the system to have evolved into a tropical storm centered about 1000 n mi west-southwest of the westernmost Azores.

In a region of weak steering currents and trapped between high pressure areas to its west and northeast, Leslie moved slowly west-southwestward to southwestward for a couple of days, and maintained an intensity of 45 to 50 kt. The system turned south-southwestward on 2 October and then became nearly stationary while gradually intensifying. By 3 October, Leslie became a hurricane with a broad ragged eye (cover image). Late that day, the cyclone began moving northward and it reached its first peak in intensity of 75 kt. A slow weakening trend began on 4 October as Leslie moved generally northward at a faster forward speed, and over slightly cooler waters. The system weakened to a tropical storm later that day while its circulation expanded in size. After its maximum winds decreased to near 50 kt on 5 October, Leslie turned toward the northeast and east while maintaining about the same intensity for a couple of days, despite being over marginal sea surface temperatures near 24°C and in an environment of moderate vertical shear. On 8 October, the storm weakened a little while turning toward the east-southeast within

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[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.

the western portion of a broad mid-tropospheric trough. A gradual re-strengthening trend began the following day while the cyclone turned toward the southeast and south-southeast. Leslie's inner-core structure became better defined, and early on 10 October the southward-moving system regained hurricane strength. Leslie continued to strengthen slowly as it turned toward the east-northeast and accelerated over slightly warmer waters, and the hurricane reached its peak intensity of 80 kt early on 12 October while centered about 575 n mi south-southwest of the westernmost Azores. Leslie was then finally picked up by the mid-latitude westerlies, and it moved swiftly east-northeastward, passing about 175 n mi north-northwest of Madeira Island at 0600 UTC 13 October. The system became a strong extratropical cyclone as it neared Portugal late on 13 October, and it crossed the coast of that country near Figuiera da Foz shortly after 2100 UTC that day. The cyclone's center became ill-defined after it moved over the Bay of Biscay on 14 October, but the system's remnants brought flooding rains to southern France on 15 October.

METEOROLOGICAL STATISTICS

Observations in Leslie (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA/JAXA 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 of Leslie.

The 2 peak intensities of the hurricane, estimated to be 75 kt and 80 kt, are based on a blend of Dvorak estimates from TAFB and SAB, ADT estimates, and (for the latter peak) ASCAT data.

Ship reports of winds of tropical storm force associated with Leslie are given in Table 2.

Large swells generated by Leslie when it was an extratropical cyclone of hurricane intensity impacted the east coast of the United States, particularly the North Carolina Outer Banks, from the end of September through early October. Large waves generated by the hurricane pounded the coast of Madeira Island on 13 October.

After Leslie became an extratropical cyclone and moved into Portugal, a wind gust to 95 kt was reported at Figuiera da Foz in that country. The remnants of the system produced over 14 inches of rain in 24 h over southern France.

CASUALTY AND DAMAGE STATISTICS

There were no reports of damage or casualties associated with Leslie while it was a tropical or subtropical cyclone. In Portugal, there was one death due to a falling tree caused by the extratropical cyclone, along with 27 injuries. Flooding from the remnants of the extratropical cyclone caused at least 10 deaths in southern France.

FORECAST AND WARNING CRITIQUE

Leslie's first genesis as a subtropical cyclone was not as well anticipated overall as its second genesis. The system that was to develop into Leslie was introduced into the 5-day Tropical Weather Outlook (TWO) with a low (<40%) probability of development 96 h prior to genesis, and into the 2-day TWO with a low probability of development 48 h before genesis (Table 3a). The 5-day and 2-day probabilities were raised to the medium (40%-60%) category 84 h and 30 h prior to genesis, respectively. The 5-day probability was raised to the high (>60%) category 48 h before genesis, and the 2-day probability never reached the high category.

It was correctly anticipated that Leslie would revert to extratropical cyclone status and subsequently redevelop into a subtropical cyclone. Leslie's second subtropical development was first mentioned in the 5-day TWO with a medium genesis probability 84 h prior to redevelopment, and was first mentioned in the 2-day TWO with a low probability of redevelopment 66 h prior to the second genesis (Table 3b). The 2-day probability was raised to the medium category 54 h prior to redevelopment, respectively, and the 5-day and 2-day probabilities were raised to high 78 h and 36 h before Leslie's second genesis.

A verification of NHC official track forecasts for Leslie is given in Table 4a. Official track forecast errors were below the mean official errors for the previous 5-yr period at 12 through 36 h, and above the 5-yr mean errors at 48 through 120 h. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. The ECMWF (EMXI) and HCCA had lower mean errors than the official forecast at all forecast intervals.

It should be noted that the track model guidance was particularly problematic late in Leslie's lifetime, creating challenges for the official forecasts. At 0000 UTC 11 October, the model guidance spread began to expand considerably beyond the 48 h forecast period in response to two possible, but contradictory, synoptic steering evolutions. A few models indicated that Leslie would accelerate within southwesterly flow ahead of an approaching shortwave trough, while the historically better-performing models, including the multi-model consensus aids, showed the system being left behind and turning southwestward, anti-cyclonically, around a reestablishing subtropical ridge. The spread of the model cluster of these two possible solutions beyond day 3 was 1000 to 2000 n mi. At 1200 UTC 11 October, the spread between the HWRF and HMON models had increased to around 2000 n mi at day 5. It wasn't until 1200 UTC 12 October that the majority of the guidance, including the consensus forecasts, indicated the correct track toward the Iberian Peninsula.

Leslie's intensity was well-predicted by the NHC. A verification of official intensity forecasts for Leslie is given in Table 5a. At all forecast intervals, the mean official intensity forecast errors were lower than the mean official errors for the previous 5-yr period. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. Overall, the HWFI and GFSI were the best-performing models for intensity, with errors that were lower than the official forecasts for the majority of forecast lead times.

Watches and warnings associated with Leslie are given in Table 6. A Tropical Storm Watch was issued for Madeira Island at 2100 UTC 11 October, and this was upgraded to a Tropical Storm Warning 6 h later. This was the first time on record that a tropical cyclone watch or warning was issued for that island.

The NHC coordinated with the meteorological services of Spain and Portugal to discuss potential wind and rainfall impacts on those countries.

ACKNOWLEDGMENTS

Table 1.   Best track for Hurricane Leslie, 23 September–13 October 2018.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 0000	35.0	45.0	1008	25	extratropical
22 / 0600	34.4	44.2	1005	30	"
22 / 1200	33.7	44.2	1003	35	"
22 / 1800	33.3	44.6	1003	35	"
23 / 0000	33.2	45.2	1003	35	"
23 / 0600	33.0	45.9	1002	35	"
23 / 1200	33.2	46.5	1002	35	subtropical storm
23 / 1800	33.5	47.0	1002	35	"
24 / 0000	33.5	47.8	1004	35	"
24 / 0600	32.9	48.5	1004	35	"
24 / 1200	32.8	47.9	1004	35	"
24 / 1800	33.0	47.6	1004	35	"
25 / 0000	32.7	47.2	1005	30	subtropical depression
25 / 0600	32.1	46.7	1005	30	"
25 / 1200	31.7	45.2	1005	30	extratropical
25 / 1800	32.9	44.3	1000	40	"
26 / 0000	32.6	42.6	998	50	"
26 / 0600	32.3	40.3	992	55	"
26 / 1200	33.8	38.5	987	55	"
26 / 1800	36.1	38.6	978	60	"
27 / 0000	37.3	40.4	970	65	"
27 / 0600	37.1	41.6	970	65	"
27 / 1200	37.0	42.5	970	65	"
27 / 1800	37.0	43.4	978	60	"
28 / 0000	36.9	44.5	983	50	"
28 / 0600	36.6	45.3	983	50	"
28 / 1200	36.4	46.4	986	45	subtropical storm
28 / 1800	36.3	47.4	986	45	"
29 / 0000	35.9	48.9	991	40	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
29 / 0600	35.4	50.0	991	40	"
29 / 1200	34.7	50.6	991	40	"
29 / 1800	34.3	51.3	991	45	tropical storm
30 / 0000	34.0	51.7	991	45	"
30 / 0600	33.8	52.2	991	45	"
30 / 1200	33.7	52.6	991	45	"
30 / 1800	33.6	53.0	991	45	"
01 / 0000	33.5	53.4	991	45	"
01 / 0600	33.3	53.7	990	50	"
01 / 1200	33.1	54.1	990	50	"
01 / 1800	32.8	54.4	990	50	"
02 / 0000	32.4	54.9	990	50	"
02 / 0600	31.9	55.4	989	55	"
02 / 1200	31.2	55.9	989	55	"
02 / 1800	30.4	56.2	986	60	"
03 / 0000	29.8	56.6	984	60	"
03 / 0600	29.6	56.8	980	65	hurricane
03 / 1200	29.5	56.8	972	75	"
03 / 1800	29.8	56.9	970	75	"
04 / 0000	30.3	57.0	972	75	"
04 / 0600	30.9	57.1	976	70	"
04 / 1200	31.7	57.2	979	65	"
04 / 1800	32.8	57.3	982	60	tropical storm
05 / 0000	34.2	57.6	984	55	"
05 / 0600	35.2	58.2	986	55	"
05 / 1200	35.9	58.3	986	55	"
05 / 1800	36.2	58.1	987	50	"
06 / 0000	36.5	57.6	987	50	"
06 / 0600	36.9	57.0	987	50	"
06 / 1200	37.4	56.4	987	50	"
06 / 1800	37.5	55.1	987	50	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
07 / 0000	37.4	53.7	987	50	"
07 / 0600	37.1	52.5	987	50	"
07 / 1200	36.5	51.6	987	50	"
07 / 1800	36.1	50.5	987	50	"
08 / 0000	35.8	49.4	989	45	"
08 / 0600	35.5	48.5	989	45	"
08 / 1200	34.9	47.4	989	45	"
08 / 1800	34.3	46.2	986	50	"
09 / 0000	33.5	45.1	983	55	"
09 / 0600	32.7	44.2	983	55	"
09 / 1200	31.6	43.6	983	55	"
09 / 1800	30.7	43.1	983	60	"
10 / 0000	29.8	42.7	981	65	hurricane
10 / 0600	28.8	42.7	981	65	"
10 / 1200	28.1	42.5	980	65	"
10 / 1800	27.7	42.2	980	65	"
11 / 0000	27.7	41.6	978	70	"
11 / 0600	28.1	40.7	978	70	"
11 / 1200	28.8	39.3	978	70	"
11 / 1800	29.5	37.5	976	75	"
12 / 0000	30.4	35.2	968	80	"
12 / 0600	31.4	32.5	968	80	"
12 / 1200	32.6	29.6	971	75	"
12 / 1800	33.4	26.3	971	75	"
13 / 0000	34.2	22.4	976	70	"
13 / 0600	35.5	18.3	977	65	"
13 / 1200	37.2	14.1	979	65	"
13 / 1800	39.3	10.5	984	60	extratropical
14 / 0000	41.1	7.6	998	40	"
14 / 0600					dissipated
12 / 0000	30.4	35.2	968	80	minimum pressure

Table 2.   Selected ship reports with winds of at least 34 kt for Hurricane Leslie, 23 September–13 October 2018.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
26 / 1800	WLPI	32.5	31.1	160 / 35	1006.3
28 / 0000	WLPI	31.2	40.2	180 / 40	1009.9
06 / 1200	SMGW	40.7	57.5	360 / 35	1005.1
07 / 0000	A8MY4	39.7	60.5	360 / 36	1014.9
07 / 1800	9V9925	38.7	56.4	020 / 35	1015.0
08 / 0600	TCZF2	39.6	50.2	030 / 35	1003.0
08 / 1200	9V9925	39.6	50.6	010 / 35	1014.0
10 / 1500	D5OX2	31.6	44.4	050 / 38	1014.5
12 / 0600	DBBH	37.8	25.1	230 / 35	999.6
12 / 0700	DBBH	37.8	25.1	240 / 41	999.6
12 / 0800	DBBH	37.8	25.1	230 / 37	1000.6
13 / 0600	WMMK	36.3	22.2	330 / 40	1010.0
13 / 1000	ZDLS1	34.1	16.8	220 / 35	1008.3
13 / 2000	9V8092	41.4	10.1	350 / 35	1008.3
14 / 0000	C6NI8	42.6	11.0	330 / 37	1008.6
14 / 0200	9V8092	39.9	10.1	310 / 38	1013.3
14 / 0300	ZCEF2	45.7	4.1	340 / 40	1004.3
14 / 0300	BATFR1	46.5	8.6	010 / 37	1007.6

Table 3a.   Number of hours in advance of the first formation of Leslie (as a subtropical storm) 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%)	48	96
Medium (40%-60%)	30	48
High (>60%)	-	54

Table 3b.   Number of hours in advance of the second formation of Leslie (as a subtropical storm) 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%)	66	-
Medium (40%-60%)	54	84
High (>60%)	36	78

Table 4a.   NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Leslie. 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	**20.2**	**30.8**	**46.6**	69.5	123.9	162.8	189.8
OCD5	54.1	133.0	226.3	329.8	467.2	545.7	653.9
Forecasts	64	60	56	52	48	47	43
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 Hurricane Leslie. 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	19.7	32.0	48.3	71.5	126.8	168.2	187.1
OCD5	54.8	137.9	236.5	337.2	462.0	547.0	636.4
GFSI	21.1	32.6	55.1	82.7	181.5	277.6	327.0
HWFI	20.1	34.1	54.5	82.4	160.1	246.6	307.3
HMNI	23.4	36.7	60.0	95.6	210.0	337.4	447.8
EGRI	22.7	42.4	58.0	75.5	**110.4**	**137.0**	**184.6**
EMXI	**18.3**	**30.0**	**43.0**	**58.6**	**88.1**	**118.8**	**172.5**
NVGI	20.5	**30.0**	**46.3**	74.6	150.9	246.5	358.4
CMCI	23.8	44.6	65.3	87.8	132.7	207.6	236.0
CTCI	22.9	37.9	59.6	84.6	157.8	232.7	273.0
GFEX	**18.5**	**28.4**	**45.4**	**66.1**	129.4	190.1	218.1
TCON	**19.4**	32.5	48.8	**71.0**	134.4	197.6	234.1
TVCA	**18.8**	**30.4**	**46.9**	**67.1**	**123.6**	180.3	205.6
TVCX	**18.4**	**29.2**	**45.2**	**64.4**	**116.5**	168.4	191.4
HCCA	**17.9**	**29.0**	**46.6**	**64.4**	**118.2**	**164.8**	**180.5**
FSSE	**18.2**	**28.3**	**42.0**	**54.4**	**93.0**	**144.3**	193.8
AEMI	20.6	**30.8**	51.9	72.8	145.4	238.7	303.1
TABS	42.3	71.4	88.0	111.4	196.0	319.7	343.3
TABM	29.3	40.1	58.8	89.7	185.7	326.4	357.3
TABD	33.2	53.7	75.2	104.1	186.2	326.9	496.2
Forecasts	57	54	50	48	44	42	37

Table 5a.   NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Leslie. 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	**3.0**	**4.2**	**4.7**	**4.7**	**6.3**	**8.3**	**9.3**
OCD5	4.2	6.2	8.1	9.5	10.3	10.1	11.2
Forecasts	64	60	56	52	49	48	44
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 Hurricane Leslie. 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	2.9	4.3	4.8	4.8	6.1	8.3	9.0
OCD5	4.3	6.4	8.1	9.6	10.5	9.3	11.3
HWFI	3.3	**4.2**	**4.6**	4.9	**5.3**	**5.5**	**6.0**
HMNI	3.6	4.5	5.2	6.3	7.1	9.4	12.4
DSHP	4.0	5.4	7.3	8.8	12.8	17.7	20.7
LGEM	3.8	5.5	7.5	8.7	11.0	12.8	13.7
ICON	3.3	4.3	5.3	6.0	7.1	9.1	10.2
IVCN	3.1	**4.2**	**4.7**	5.2	6.6	8.6	9.6
CTCI	4.6	5.6	6.2	5.9	**5.7**	9.2	12.5
GFSI	3.6	4.5	**4.6**	**4.7**	**4.3**	**7.8**	9.2
EMXI	3.9	5.8	6.7	7.7	9.8	11.7	**8.7**
HCCA	3.3	4.4	4.8	5.5	**5.2**	**8.2**	9.3
FSSE	3.2	4.7	5.3	5.9	6.4	8.3	10.3
Forecasts	61	58	54	50	46	42	36

Table 6.   Watch and warning summary for Hurricane Leslie.

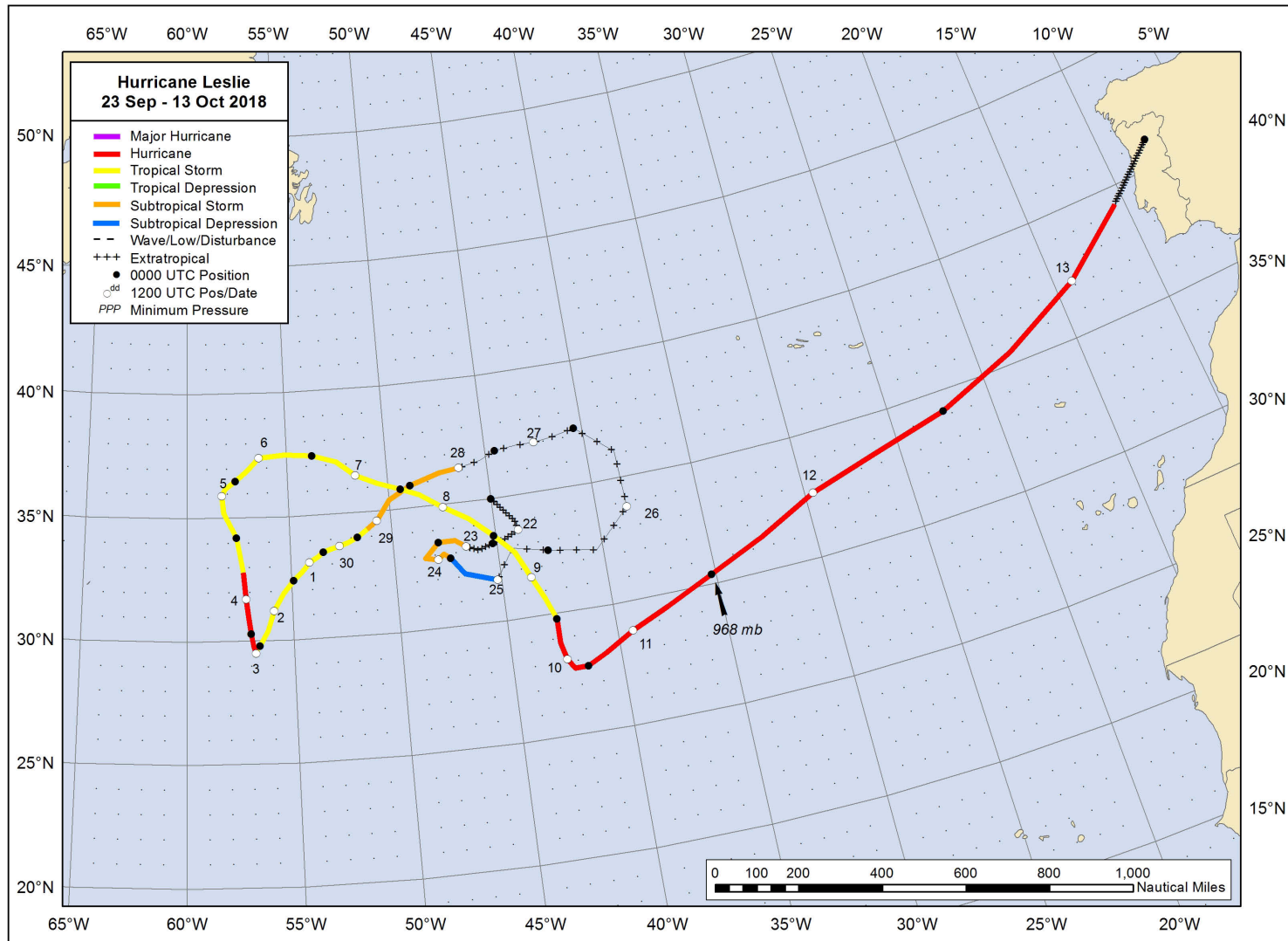| Date/Time (UTC)	Action	Location
11 / 2100	Tropical Storm Watch issued	Madeira Island
12 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Madeira Island
13 / 1200	Tropical Storm Warning discontinued	All

Figure 1.   Best track positions for Hurricane Leslie, 23 September–13 October 2018. Tracks during the extratropical stages are partially based on analyses from the NOAA Ocean Prediction Center.
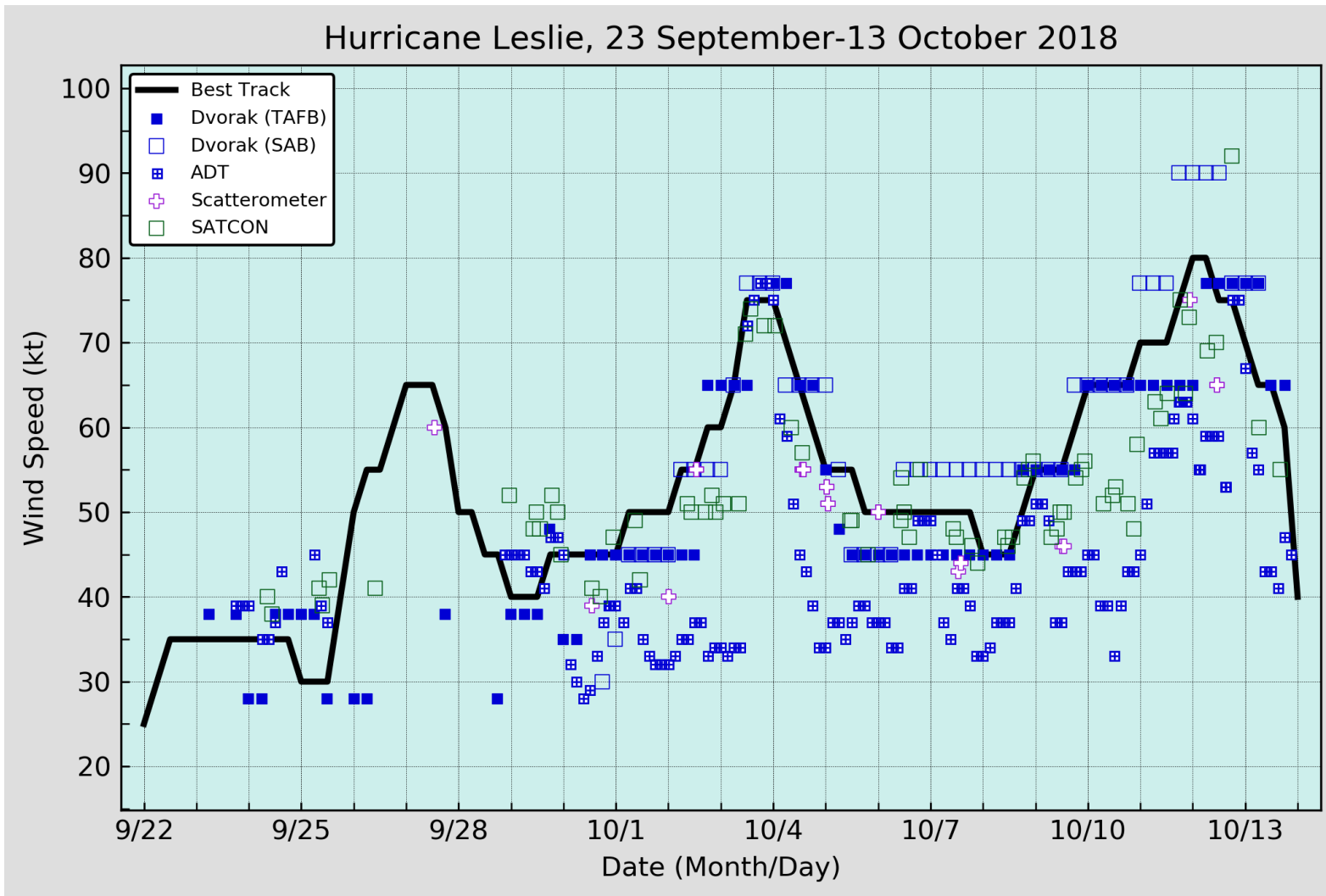
Figure 2.   Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Leslie, 23 September–13 October 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.
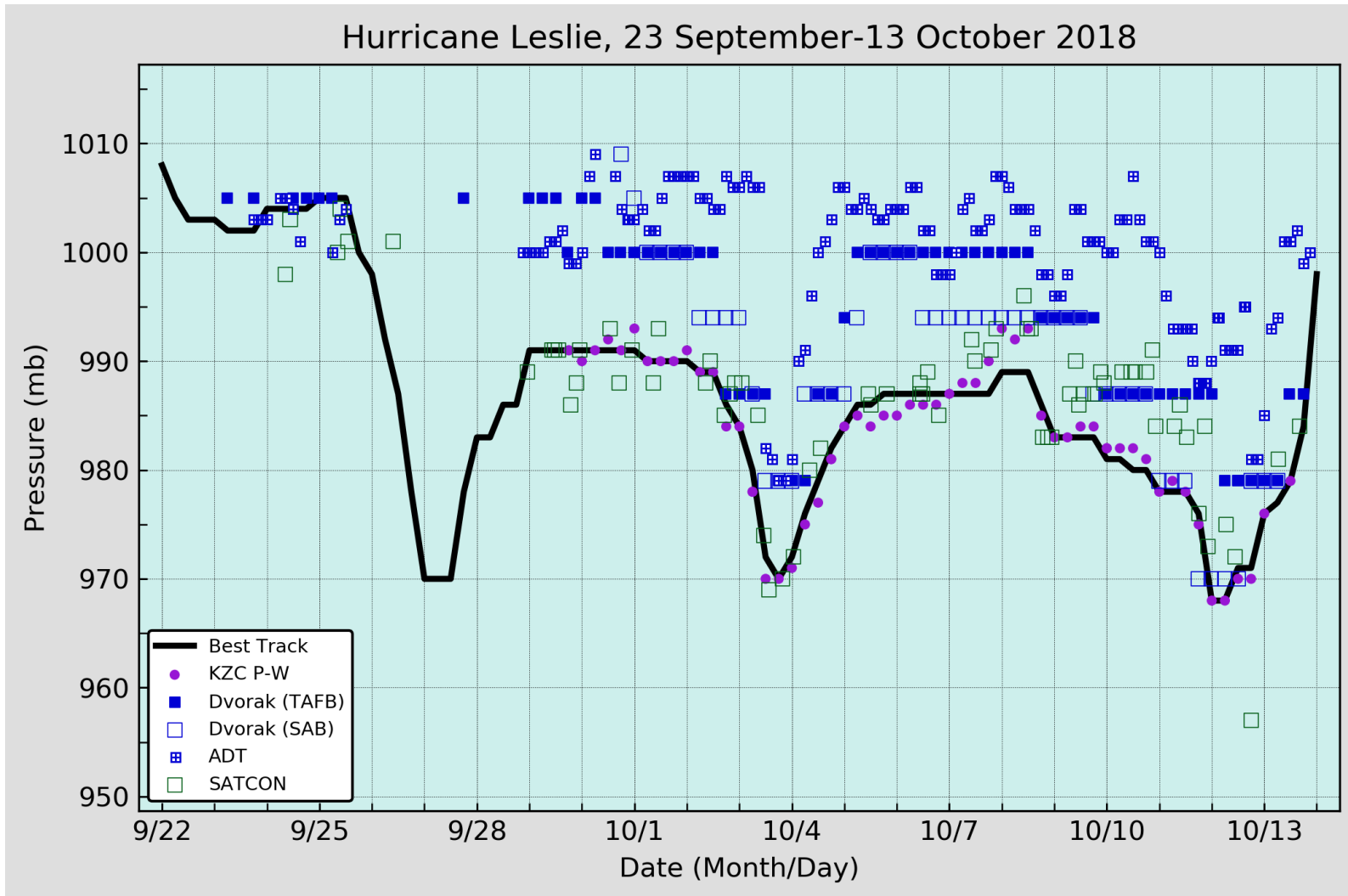
Figure 3.   Selected pressure observations and best track minimum central pressure curve for Hurricane Leslie, 23 September–13 October 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.