NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE LEE

(AL142017)

14–30 September 2017

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LEE NEAR PEAK INTENSITY AT 1451 UTC 27 SEPTEMBER 2017. IMAGE COURTESY ANTTI LIPPONEN, BASED ON NASA TERRA MODIS DATA.

Lee was a long-lived cyclone that began as a weak storm over the far eastern tropical Atlantic. It dissipated without much fanfare several days after formation, but regenerated over the subtropical Atlantic as a result of a trough interaction. After becoming trapped under a mid-latitude ridge and performing a sharp cusp, the small storm turned west-southwestward, eventually becoming a larger category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) before recurving well east of Bermuda.

Hurricane Lee

14–30 SEPTEMBER 2017

SYNOPTIC HISTORY

Lee originated from a strong tropical wave that moved off the west African coast on 13 September. A weak convectively coupled Kelvin wave passing through the region probably enhanced the wave's thunderstorm activity when it came off the coast. A broad surface low was noted early the next day, and convection increased near the low with a distinct symmetric satellite appearance. It is estimated from satellite data that the low became a tropical depression near 1800 UTC 14 September while centered about 265 n mi south of the Cabo Verde Islands. The depression then moved westward to west-northwestward beneath a mid-level ridge over the eastern Atlantic Ocean. Moderate northerly shear and some dry air in the mid-levels of the atmosphere kept the depression from intensifying much, with the center exposed at times during the following two days. Scatterometer data, however, indicated that the depression had become a tropical storm and maintained 35-kt winds for about a day, beginning near 1200 UTC 16 September when located a few hundred miles southwest of the Cabo Verde Islands. The "best track" chart of Lee'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].

The marginal environment became unfavorable for strengthening after 17 September, and the cyclone weakened due to northwesterly shear and continued dry air entrainment. Periodic bursts of convection formed near the center, but they were quickly sheared away by strong upper-level winds. Finally on 19 September, the deep convection was better maintained as the system interacted with a mid-tropospheric trough, and scatterometer data indicated that Lee became a tropical storm again, this time with 40-kt winds. The storm turned northwestward due to the influence of the trough, but this feature also quickly caused a notable increase in shear. By 1200 UTC 20 September, when Lee was about 1000 n mi east of the northern Leeward Islands, the cyclone's low-level center opened up into a trough, and the cyclone decoupled, with the mid-level circulation accelerating rapidly north-northeastward.

Although this type of trough interaction is usually fatal to a tropical cyclone, deep convection persisted near the mid-level center while it moved to the north and north-northwest around the mid-latitude trough, and high shear caused the old surface trough to weaken. The best track follows the mid-level system since by late on 21 September, satellite imagery indicated that a rather small low-level circulation was already trying to re-form beneath the mid-level center at higher latitudes. Convection increased early the next day, while the disturbance was in a lower-shear environment on the northern side of the trough, and Lee regenerated into a tropical depression near 1200 UTC 22 September about 825 n mi east-southeast of Bermuda.

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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 very small cyclone gradually intensified over the central Atlantic within an environment of low shear and warm water, drifting generally north-northwestward. Late on 23 September, the storm began moving slowly southward as a central Atlantic ridge blocked it from recurving. A symmetric area of deep convection then formed over the center of Lee, and microwave data showed that a mid-level eye was present. Lee rapidly intensified into a hurricane early on 24 September, with a tiny clear eye on satellite images. The hurricane drifted southeastward and then southwestward from 24–25 September, maintaining an intensity of about 80 kt due to some northeasterly shear. Late on 25 September, Lee completed an eyewall cycle, forming a larger eye in the process, and began to intensify again. The cyclone accelerated westward on 26 September while it slowly strengthened, moving around a strong ridge over the central Atlantic. Lee again went through a quick ~12-h eyewall replacement that evening, which resulted in another increase in the eye diameter on 27 September. The hurricane turned northwestward and reached its peak intensity of 100 kt at 1200 UTC that day (cover image) about 435 n mi east-southeast of Bermuda. Lee maintained that intensity for about 12 h before starting to weaken late that day while moving northward.

The cyclone gradually turned northeastward and accelerated in that direction, continuing to slowly weaken during the next two days due to cooler waters and increasing vertical shear. Lee decayed to a tropical storm late on 29 September and lost all of its deep convection early the next day. The storm became a post-tropical low at 0600 UTC 30 September about 400 n mi northwest of the Azores, and it opened up into a trough 6 h later over the far North Atlantic.

METEOROLOGICAL STATISTICS

Observations in Lee (Figs. 3 and 4) 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 from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison (UW-CIMSS). 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 of Lee.

The estimated peak intensity of 100 kt was based on a blend of Dvorak satellite estimates from TAFB, SAB and UW-CIMSS ADTs.

Note that the final best track between dissipation (0600 UTC 20 September) and regeneration (1200 UTC 22 September) was tracking the mid-level remnants of Lee, and not the original surface low, since the mid-level circulation caused the reformation.

There were no ship reports or land stations with tropical-storm-force winds in association with Lee.

CASUALTY AND DAMAGE STATISTICS

There were no deaths or damage attributable to Lee.

FORECAST AND WARNING CRITIQUE

The genesis forecasts for Lee were below average. The first mention of the tropical Atlantic precursor system in the Tropical Weather Outlook (TWO) was only 18 h before it became a depression, and it was only given a low chance (<40%) of formation (Table 2a). The re-formation of Lee at higher latitudes was somewhat better anticipated, with the system entering the TWO 60 h before it formed, with a high chance (>60%) in the 5-day prediction 54 h before genesis (Table 2b). However, the system was removed from the TWO on the day before it formed, and it was not reinserted until after reformation in the best track. The extremely small size of Lee contributed to the poor genesis forecasts, with very little global model support for Lee reforming in the subtropical Atlantic Ocean.

A verification of NHC official track forecasts (OFCL) for Lee is given in Table 3a. Official forecast track errors were much higher than the mean official errors for the previous 5-yr period. This isn't too surprising given the regeneration and unusual path of Lee, which led to a difficult set of track forecasts that had the highest errors around the time of the tropical cyclone's regeneration. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The ECMWF model (EMXI) performed quite well for this cyclone, beating all of the guidance (and OFCL) at every time period. It was the first model that picked up on the eventual left turn of Lee in the subtropical Atlantic, well before the rest of the guidance (Figs. 4a, b). The GFS (GFSI) and its ensemble mean (AEMI) struggled with Lee's track.

A verification of NHC official intensity forecasts for Lee is given in Table 4a. Official forecast intensity errors were below the mean official errors for the previous 5-yr period through 96 h, then near average at 120 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The intensity consensus (ICON) was difficult to beat at any given time period. Among the individual models, the HWRF model (HWFI) had a good performance, while the global models (GFS, ECMWF) provided generally poor guidance (e.g. Fig 5). It is not surprising, in retrospect, that the global models had a tough time with the intensity forecast of Lee considering the rather small size of the cyclone.

There were no land-based watches or warnings issued for Lee.

Table 1. Best track for Hurricane Lee, 14–30 September 2017.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
14 / 1800	10.4	23.1	1011	25	tropical depression
15 / 0000	10.6	24.7	1010	30	"
15 / 0600	11.1	26.2	1008	30	"
15 / 1200	11.7	27.6	1008	30	"
15 / 1800	12.4	29.0	1009	30	"
16 / 0000	12.6	30.5	1009	30	"
16 / 0600	12.6	31.9	1008	30	"
16 / 1200	12.5	33.1	1007	35	tropical storm
16 / 1800	12.6	33.9	1007	35	"
17 / 0000	12.7	34.6	1007	35	"
17 / 0600	12.8	35.4	1007	35	"
17 / 1200	12.9	36.2	1008	30	tropical depression
17 / 1800	13.1	37.0	1008	30	"
18 / 0000	13.4	37.9	1008	30	"
18 / 0600	13.8	39.0	1008	30	"
18 / 1200	14.2	40.2	1008	30	"
18 / 1800	14.5	41.5	1008	30	"
19 / 0000	14.9	42.6	1009	25	"
19 / 0600	15.5	43.3	1009	25	"
19 / 1200	16.1	43.8	1008	30	"
19 / 1800	16.8	44.4	1007	35	tropical storm
20 / 0000	17.6	45.0	1006	40	"
20 / 0600	18.3	45.2	1007	35	"
20 / 1200	20.4	44.1	1009	30	disturbance
20 / 1800	22.0	43.9	1011	30	"
21 / 0000	23.8	43.9	1015	25	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 0600	26.5	45.3	1016	25	"
21 / 1200	27.8	46.5	1016	25	"
21 / 1800	28.8	47.5	1016	25	"
22 / 0000	29.3	48.3	1016	25	"
22 / 0600	29.6	48.7	1016	25	"
22 / 1200	30.0	48.9	1014	25	tropical depression
22 / 1800	30.5	49.1	1012	30	"
23 / 0000	31.1	49.2	1010	35	tropical storm
23 / 0600	31.5	49.3	1009	35	"
23 / 1200	31.8	49.4	1006	40	"
23 / 1800	32.0	49.8	1003	45	"
24 / 0000	31.9	50.1	1000	50	"
24 / 0600	31.7	50.2	990	65	hurricane
24 / 1200	31.5	50.1	983	75	"
24 / 1800	31.3	49.8	980	80	"
25 / 0000	31.2	49.6	976	85	"
25 / 0600	31.0	49.5	978	80	"
25 / 1200	30.8	49.7	980	80	"
25 / 1800	30.6	50.2	984	75	"
26 / 0000	30.3	51.0	982	80	"
26 / 0600	30.1	52.0	979	85	"
26 / 1200	29.9	53.2	976	90	"
26 / 1800	29.9	54.2	972	95	"
27 / 0000	29.9	55.1	970	95	"
27 / 0600	30.1	56.0	967	95	"
27 / 1200	30.3	56.6	963	100	"
27 / 1800	30.8	57.0	962	100	"
28 / 0000	31.4	57.2	965	95	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 0600	32.1	57.3	969	90	"
28 / 1200	33.0	57.2	973	85	"
28 / 1800	34.3	56.6	977	80	"
29 / 0000	35.7	55.5	981	75	"
29 / 0600	37.3	53.8	983	70	"
29 / 1200	39.0	51.2	985	65	"
29 / 1800	41.0	48.2	987	55	tropical storm
30 / 0000	43.2	44.5	990	50	"
30 / 0600	45.8	38.9	993	45	low
30 / 1200					dissipated
27 / 1800	30.8	57.0	962	100	minimum pressure and maximum wind

Table 2a. Number of hours in advance of the first formation of Lee in the deep Tropics 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%)	18	18
Medium (40%-60%)	-	-
High (>60%)	-	-

Table 2b. Number of hours in advance of reformation of Lee in the subtropical Atlantic 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%)	60	60
Medium (40%-60%)	57	57
High (>60%)	-	54

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Lee. 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	28.2	52.0	75.5	103.5	176.2	256.8	359.0
OCD5	45.9	104.5	171.6	238.3	388.6	519.2	631.7
Forecasts	45	42	40	36	28	20	12
OFCL (2012-16)	24.9	39.6	54.0	71.3	105.8	155.4	208.9
OCD5 (2012-16)	47.3	103.9	167.8	230.3	343.1	442.6	531.0

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Lee. 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 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	28.7	53.5	75.2	102.1	159.7	209.8	304.4
OCD5	44.4	101.0	172.2	225.6	357.6	489.3	543.6
GFSI	34.9	66.1	96.4	133.8	211.3	302.5	456.8
AEMI	37.0	72.8	106.2	142.8	226.6	338.3	536.7
HWFI	31.9	57.2	81.2	108.0	168.3	227.2	381.4
HMNI	34.2	68.0	101.4	144.1	231.9	317.9	509.7
EMXI	**25.0**	**44.6**	**62.6**	**85.4**	**128.8**	**167.3**	**203.3**
CTCI	33.0	67.0	95.2	128.2	196.4	274.6	412.6
TVCN	29.6	55.3	79.5	107.9	160.4	213.1	315.5
TVCX	**27.9**	**52.7**	75.7	103.1	**150.7**	**199.5**	**292.2**
HCCA	29.8	55.1	77.2	103.6	**152.7**	**198.8**	323.4
GFEX	29.4	54.7	77.2	105.0	160.0	221.9	323.2
TABD	43.3	93.2	150.7	204.0	313.8	437.9	509.5
TABM	33.6	71.1	123.6	182.1	280.6	367.1	482.6
TABS	31.2	69.5	115.4	162.2	237.6	317.9	508.0
Forecasts	37	34	33	30	23	16	8

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Lee. 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	**4.3**	**6.8**	**10.0**	**11.4**	**11.3**	**13.5**	14.6
OCD5	5.4	9.5	13.9	17.3	23.5	27.3	22.0
Forecasts	45	42	40	36	28	20	12
OFCL (2012-16)	5.5	8.2	10.5	12.0	13.4	14.0	14.5
OCD5 (2012-16)	7.1	10.5	13.0	15.1	17.4	18.2	20.6

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Lee. 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	4.5	7.1	9.9	10.8	11.3	11.7	9.5
OCD5	5.5	10.0	14.0	17.7	24.1	26.6	18.5
HWFI	**4.1**	**6.9**	**8.6**	**9.5**	**10.5**	12.1	12.8
DSHP	4.7	7.6	**9.6**	**10.4**	12.0	11.7	11.6
LGEM	4.5	7.3	**8.8**	**8.4**	**10.9**	13.1	**6.9**
ICON	**4.0**	**6.5**	**8.2**	**8.8**	**10.5**	**11.6**	**8.8**
IVCN	**4.0**	**6.7**	**8.6**	**9.5**	**10.9**	11.7	9.7
HCCA	**3.7**	**6.8**	**8.8**	**9.2**	12.2	13.4	13.4
HMNI	8.0	11.6	13.2	14.7	11.3	**8.3**	12.1
GFSI	6.2	9.9	13.4	15.6	16.9	20.4	21.1
EMXI	6.6	10.6	13.3	15.3	20.5	27.8	30.4
Forecasts	42	39	38	33	26	18	10

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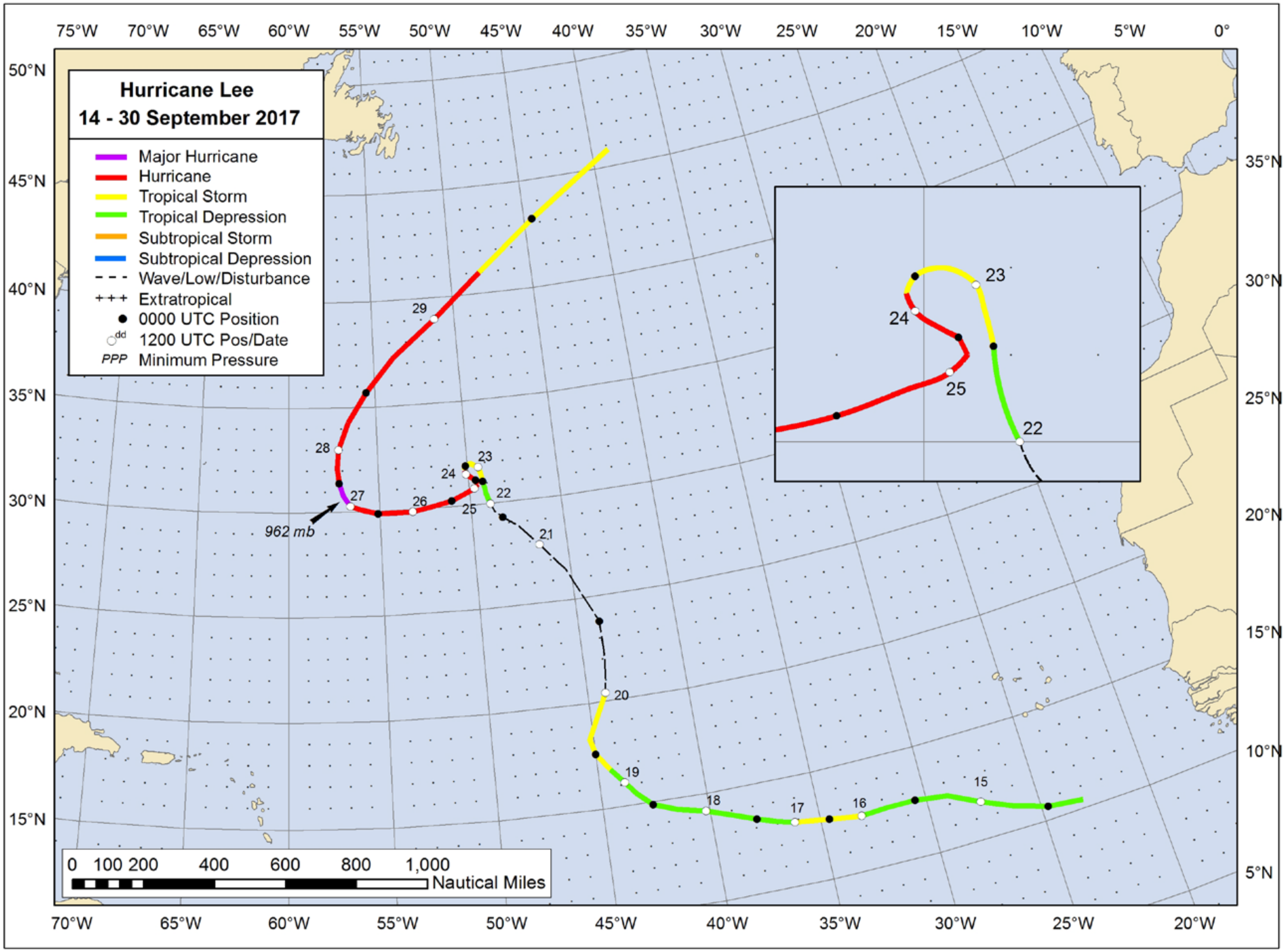

Figure 1. Best track positions for Hurricane Lee, 14–30 September 2017.

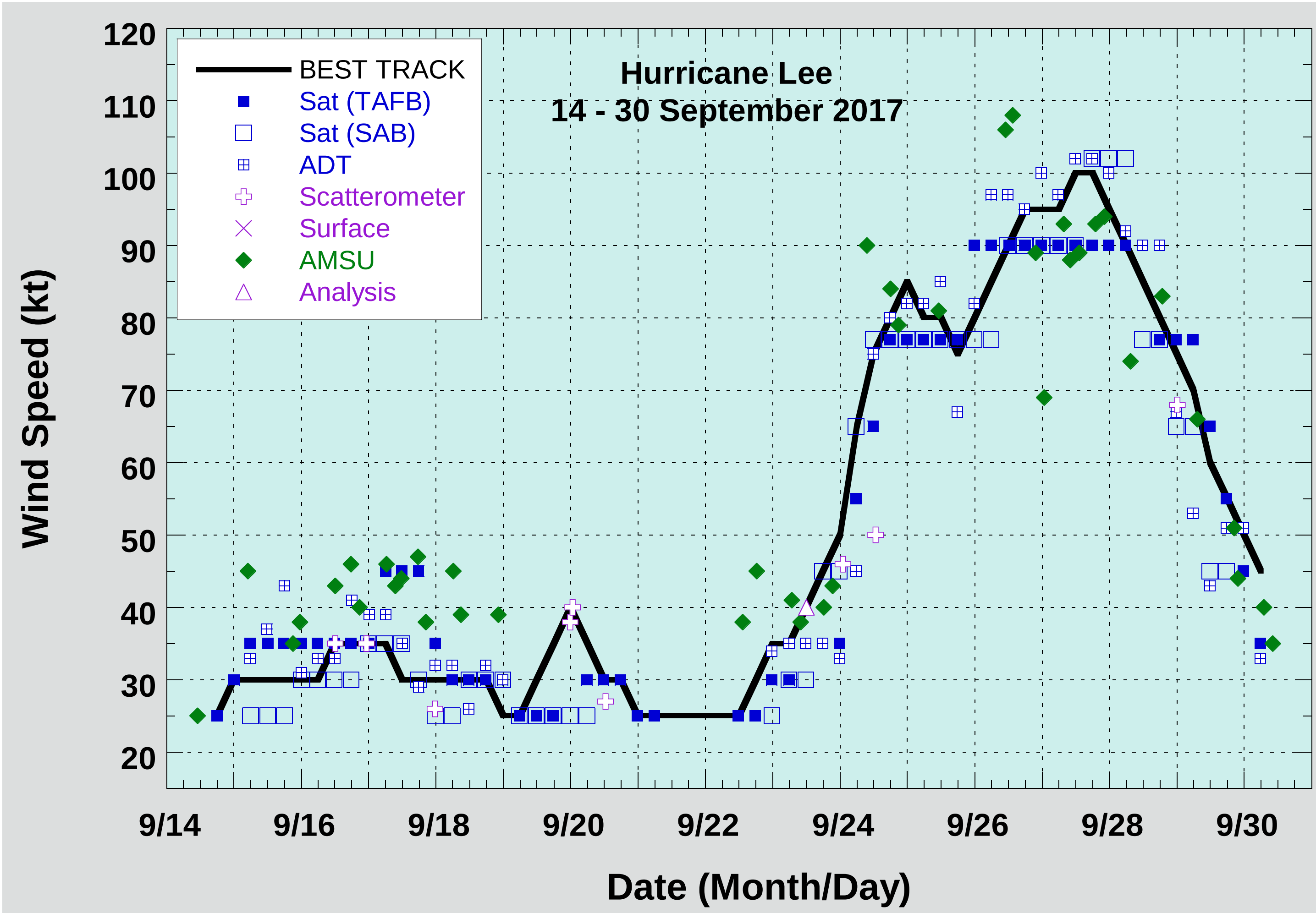

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Lee, 14–30 September 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

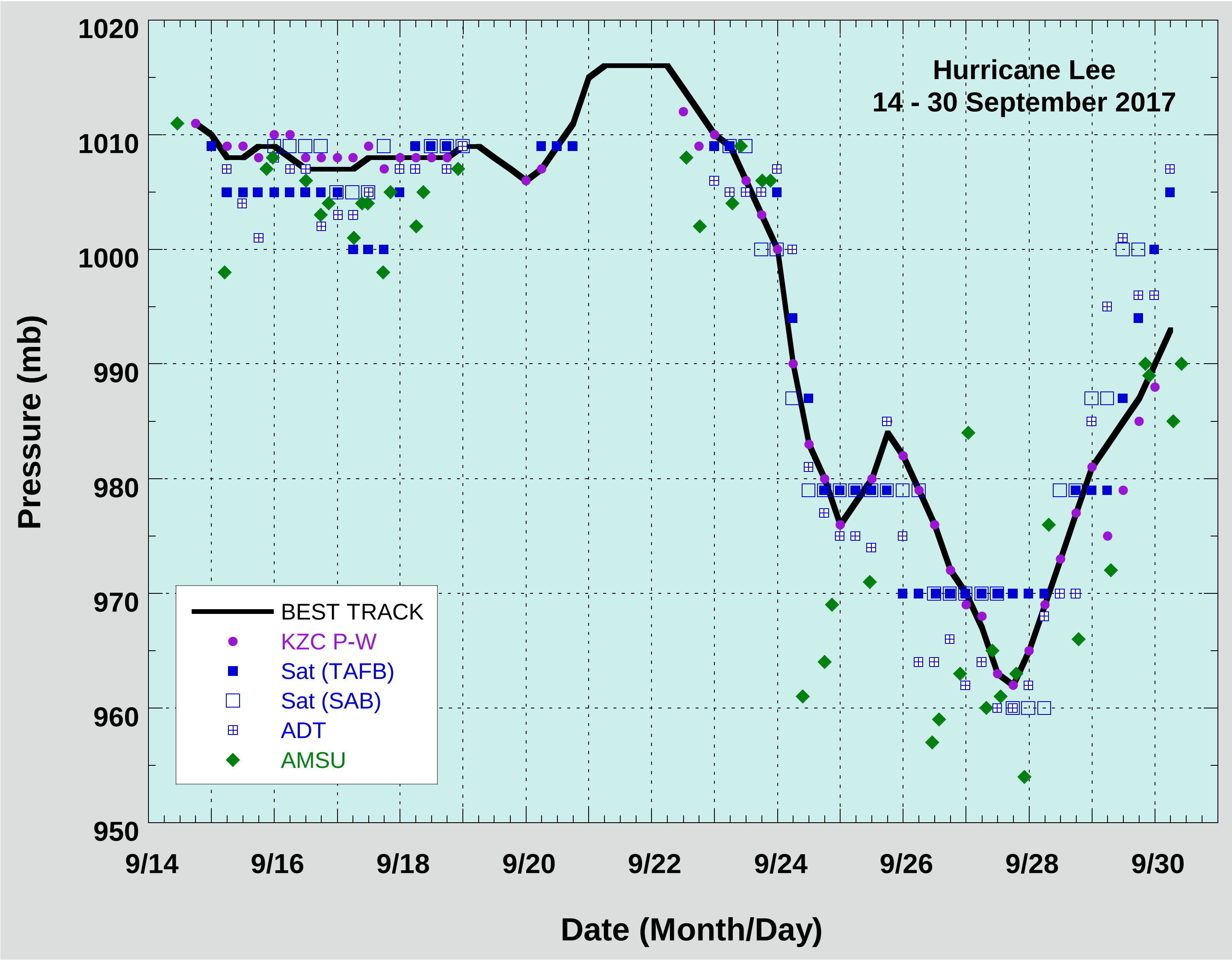

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Lee, 14–30 September 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.

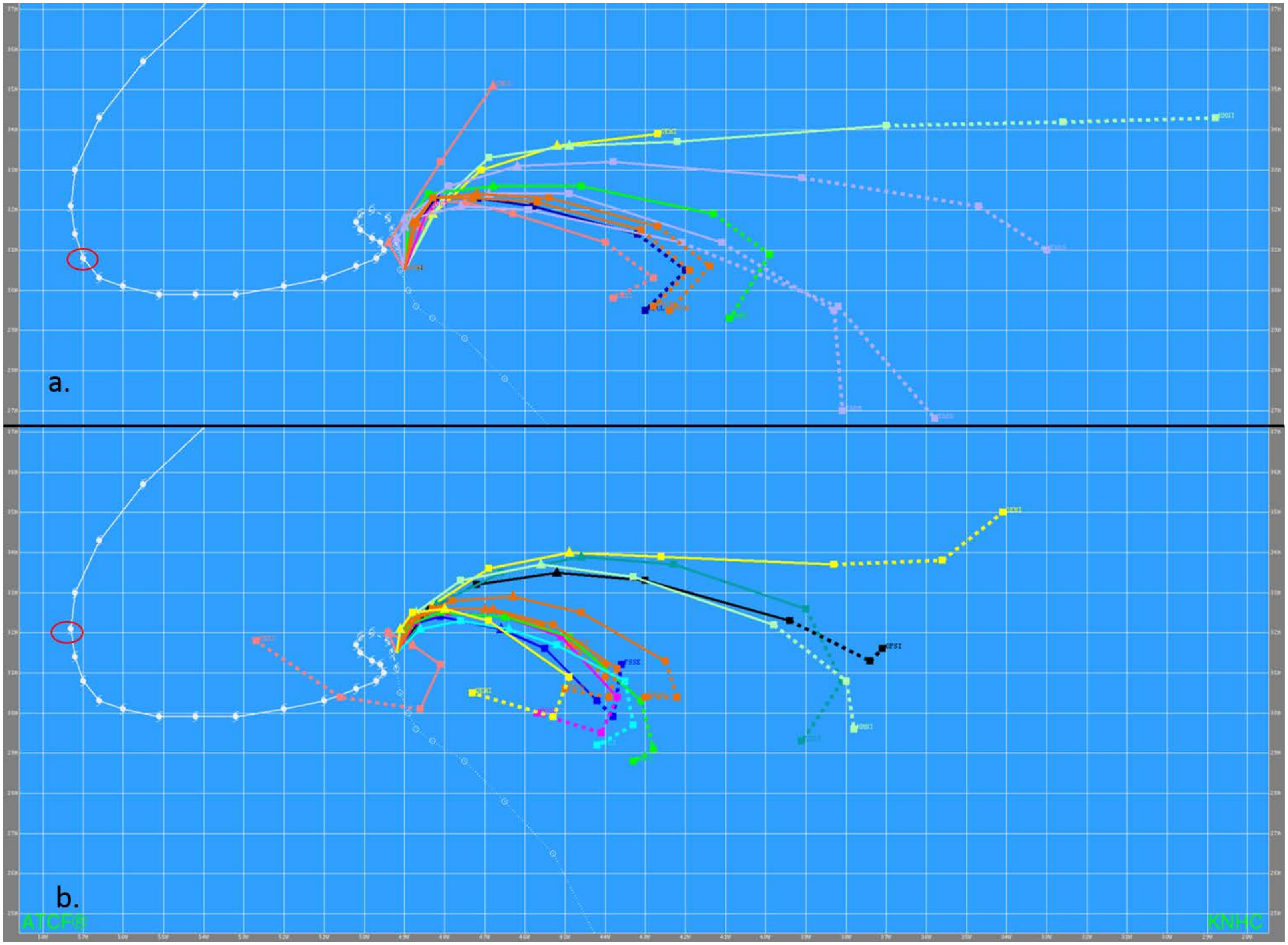

Figure 4. NHC track aids (colored lines) for Lee for forecasts cycles at a) 1800 UTC 22 September 2017 and b) 0600 UTC 23 September 2017. The best track in shown in white, and the verifying 120 h positions are circled in red.

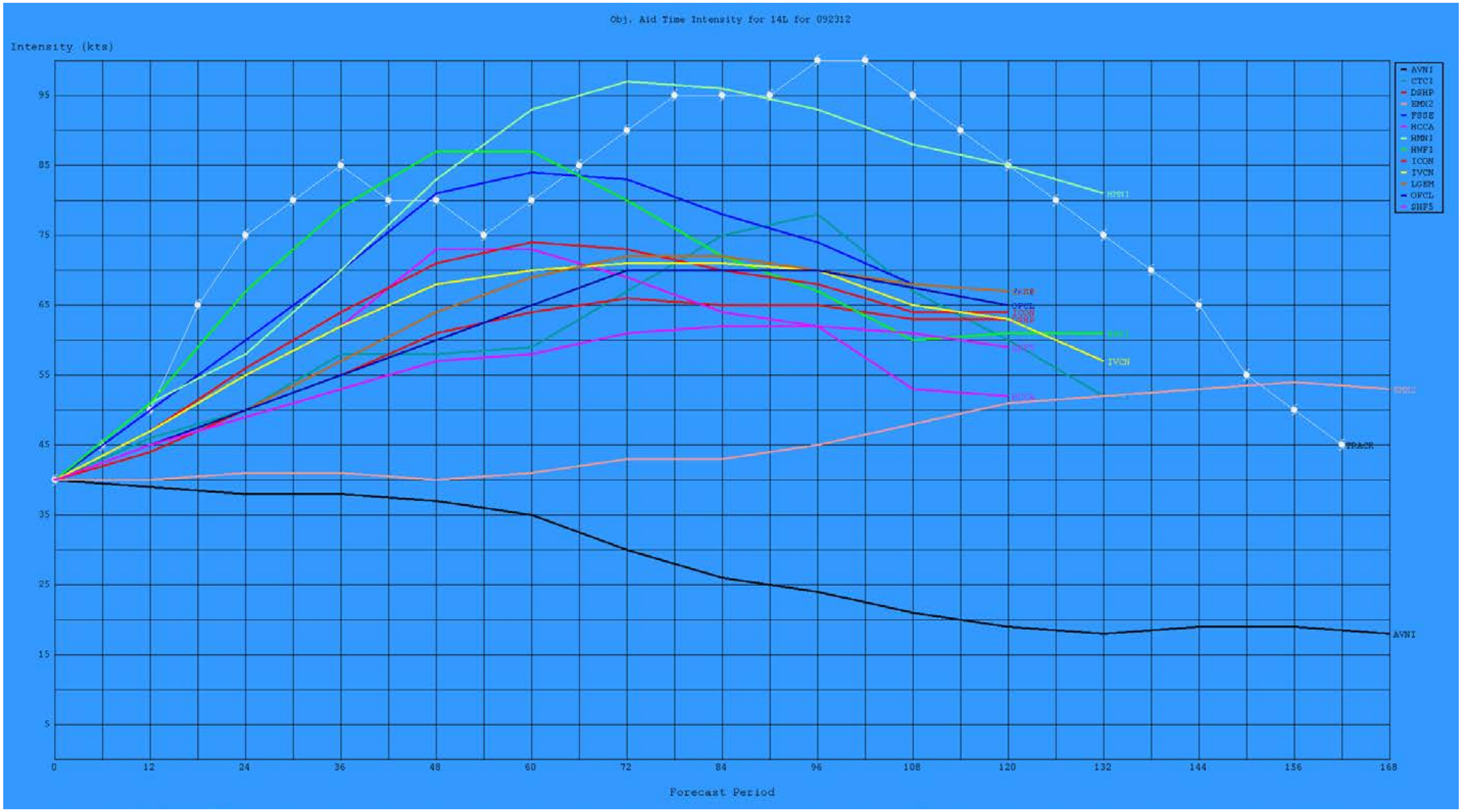

Figure 5. NHC intensity aids (knots, colored lines) for Lee for the 1200 UTC 23 September 2017 forecast cycle (verifying intensity shown in white). Note the global guidance (orange - ECMWF, black - GFS) was much lower than the rest of the guidance.