NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM ESTELLE

(EP062016)

15 – 21 July 2016

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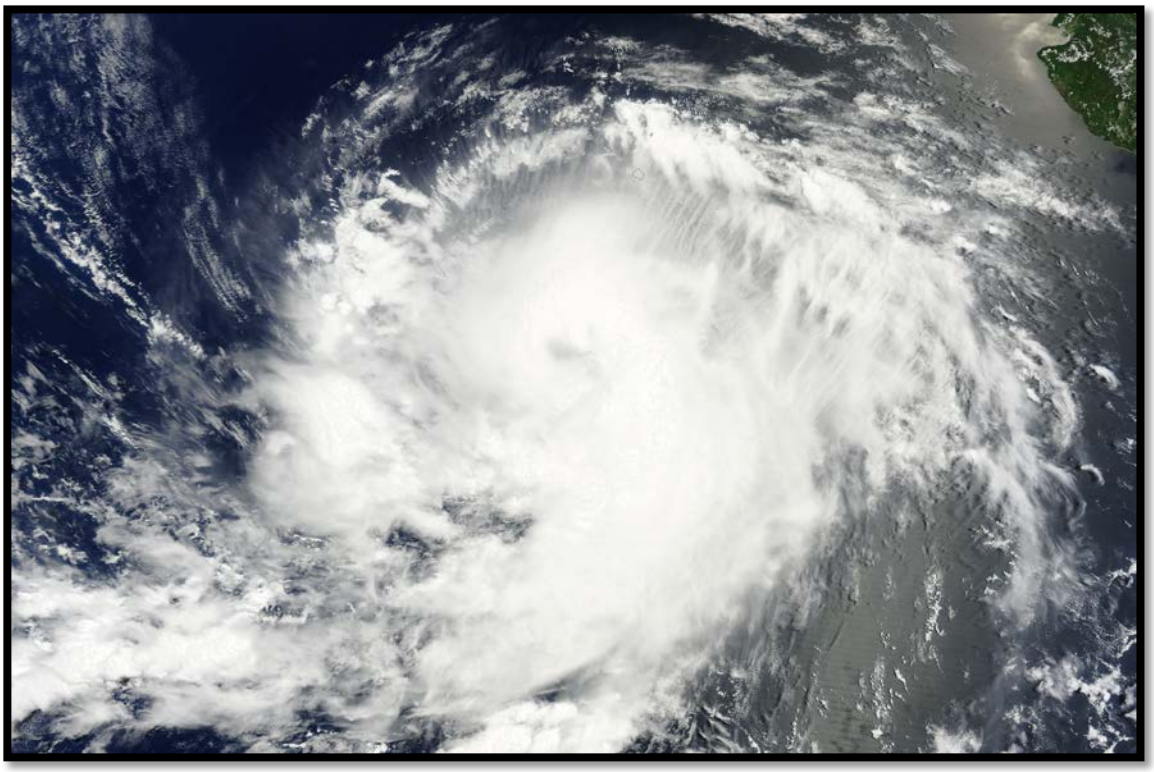

NASA TERRA/MODIS VISIBLE SATELLITE IMAGE OF TROPICAL STORM ESTELLE AT 1755 UTC 17 JULY 2016 WHEN IT FIRST REACHED ITS PEAK INTENSITY

Estelle was a tropical storm that moved west-northwestward away from the coast of Mexico and was close to becoming a hurricane. Estelle produced sustained tropical-storm-force winds and gusts to hurricane force on Clarion Island.

Tropical Storm Estelle

15 – 21 JULY 2016

SYNOPTIC HISTORY

Estelle originated from a tropical wave that moved off the west coast of Africa on 4 July. The wave moved westward across the tropical Atlantic, reached the eastern Caribbean Sea on 10 July, and then moved across Central America into the eastern Pacific basin on 12 and 13 July. Disorganized showers and a few thunderstorms accompanied the wave on 14 July, and satellite images indicated that a well-defined low pressure system formed around 0000 UTC 15 July a few hundred miles southwest of the coast of southern Mexico. A tropical depression formed later that day when the deep convection increased in coverage and became more organized, and the system strengthened to a tropical storm by 0000 UTC 16 July while centered about 310 n mi south-southwest of Manzanillo, Mexico. 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[1].

When Estelle formed, strong mid-tropospheric high pressure was centered over the United States-Mexico border extending westward over the Pacific Ocean. The high caused Estelle to move westward and west-northwestward initially, traversing sea surface temperatures that were between 28 and 29°C for the first few days of the cyclone's existence. However, moderate northeasterly shear persisted during that same period, and Estelle only gradually intensified, reaching a peak intensity of 60 kt at 1800 UTC 17 July while it was centered about 400 n mi south-southwest of the southern tip of the Baja California peninsula. Estelle displayed a ragged eye in visible satellite images at the time (see cover image), but the feature did not persist for long.

Even though vertical shear decreased below 10 kt soon after Estelle reached its peak intensity, the cyclone was unable to generate much inner-core convection (Fig. 4a), and it weakened slightly on 18 July while passing about 35 n mi south of Clarion Island. The cyclone probably had its best presentation early on 20 July when microwave imagery revealed a small mid-level eye feature (Fig. 4b). However, further strengthening was likely prevented by cooler sea surface temperatures, which fell below 26°C by 0600 UTC 20 July. Estelle proceeded to gradually weaken over even cooler waters, and it became a post-tropical cyclone around 0000 UTC 22 July when it was no longer producing significant deep convection. The post-tropical cyclone weakened further, with the remnant low dissipating shortly after 0600 UTC 24 July about 800 n mi east-northeast of the Hawaiian Islands.

[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.

METEOROLOGICAL STATISTICS

Observations in Estelle (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 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 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 Estelle.

Estelle's estimated peak intensity of 60 kt between 1800 UTC 17 July and 0600 UTC 18 July is supported by a blend of subjective satellite intensity estimates that were 65 kt, objective satellite intensity estimates that were between 55-60 kt, and an ASCAT pass that showed maximum winds also between 55-60 kt. There is less confidence in the second 60-kt peak intensity between 1200 UTC 19 July and 1200 UTC 20 July. Satellite intensity estimates again were 65 kt from TAFB and SAB during that period, but ADT estimates were only between 35-40 kt. Since Estelle's best presentation in microwave imagery occurred early on 20 July (Fig. 4b), the estimated intensity is much closer to the subjective numbers around that time.

An automated Mexican navy station on Clarion Island measured a peak sustained wind of 51 kt and a gust to 72 kt at 1300 UTC 18 July. There were no credible ship reports of winds of tropical storm force associated with Estelle.

CASUALTY AND DAMAGE STATISTICS

There were no reports of damage or casualties associated with Estelle.

FORECAST AND WARNING CRITIQUE

Estelle's genesis was forecast reasonably well, but it occurred a little earlier than expected. Table 2 provides the number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. A low (< 40%) chance of genesis during the next five days was introduced into the TWO 102 h before Estelle formed, and the probability was raised to a high (> 60%) chance 72 h before genesis. The precursor disturbance was only given a low chance of formation during the next two days 48 h before genesis, and the two-day probability was raised to a high chance 18 h before genesis.

A verification of NHC official track forecasts for Estelle is given in Table 3a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at all forecast times. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Forecasts from the United Kingdom Met Office model (EGRI), and

by extension the TCON consensus, were not available coincidentally with at least two-thirds of NHC forecasts and were therefore not included in the homogenous sample. The NHC official track forecasts had overall lower errors than the individual track models, but several of the model consensus aids had even lower errors through 72 h. In particular, the TVCX multi-model consensus, which doubles the weight of the ECMWF model, and the Florida State Superensemble (FSSE) had lower errors than the NHC official forecasts at all forecast times through 72 h. The NHC track forecasts excelled at days 4 and 5, beating every individual track model and consensus aid with the exception of the medium-layer Beta and advection model (BAMM) at 96 h.

A verification of NHC official intensity forecasts for Estelle is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period between 12-48 h and at 120 h and were higher between 72-96 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The NHC official intensity forecasts were not skillful compared to any of the individual intensity models or consensus aids except for FSSE, which had larger errors at all forecast times. The NHC forecasts had a significant high bias (as much as 15-20 kt too high at 72-96 h), with a majority of the forecasts indicating that Estelle would reach hurricane intensity. Most of the intensity models also displayed a consistent high bias, and only the Logistic Growth Equation Model (LGEM) showed no intensity bias through all forecast times.

No coastal tropical cyclone watches or warnings were issued in association with Estelle.

Table 1. Best track for Tropical Storm Estelle, 15-21 July 2016.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
15 / 0000	13.5	104.5	1008	25	low
15 / 0600	13.7	105.2	1008	25	"
15 / 1200	14.0	106.0	1008	25	tropical depression
15 / 1800	14.4	106.7	1007	30	"
16 / 0000	14.8	107.4	1005	35	tropical storm
16 / 0600	15.3	108.1	1004	40	"
16 / 1200	15.7	108.7	1003	45	"
16 / 1800	15.9	109.4	1002	45	"
17 / 0000	16.0	110.1	1000	45	"
17 / 0600	16.1	110.8	998	50	"
17 / 1200	16.3	111.5	994	55	"
17 / 1800	16.5	112.2	990	60	"
18 / 0000	16.8	113.0	990	60	"
18 / 0600	17.2	113.7	990	60	"
18 / 1200	17.6	114.4	991	55	"
18 / 1800	17.9	115.3	992	55	"
19 / 0000	18.1	116.2	993	55	"
19 / 0600	18.4	117.1	993	55	"
19 / 1200	18.7	118.1	992	60	"
19 / 1800	18.9	119.2	991	60	"
20 / 0000	19.0	120.4	990	60	"
20 / 0600	19.0	121.6	990	60	"
20 / 1200	19.1	122.7	990	60	"
20 / 1800	19.2	123.8	992	55	"
21 / 0000	19.3	124.9	994	55	"
21 / 0600	19.5	126.1	996	55	"
21 / 1200	19.9	127.4	999	50	"
21 / 1800	20.4	128.9	1002	45	"
22 / 0000	20.8	130.2	1004	40	low
22 / 0600	21.1	131.5	1005	35	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 1200	21.5	132.8	1005	35	"
22 / 1800	22.1	134.1	1006	30	"
23 / 0000	22.6	135.3	1007	30	"
23 / 0600	23.0	136.4	1008	30	"
23 / 1200	23.4	137.5	1009	30	"
23 / 1800	23.7	138.8	1010	25	"
24 / 0000	24.0	140.1	1010	25	"
24 / 0600	24.3	141.6	1010	25	"
24 / 1200					dissipated
17 / 1800	16.5	112.2	990	60	maximum winds and minimum pressure

Table 2. Number of hours in advance of formation 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	102
Medium (40%-60%)	36	84
High (>60%)	18	72

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Estelle, 15-21 July 2016. 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	**15.5**	**24.5**	**29.4**	**40.4**	**54.3**	**51.2**	**33.4**
OCD5	20.7	41.0	62.1	85.5	122.1	155.9	198.5
Forecasts	24	22	20	18	14	10	6
OFCL (2011-15)	23.4	36.4	47.2	59.4	89.0	123.6	159.5
OCD5 (2011-15)	36.6	74.2	116.5	159.7	245.6	331.1	427.4

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Estelle, 15-21 July 2016. 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	15.5	21.1	25.7	35.9	47.0	43.8	28.8
OCD5	21.5	44.1	66.5	92.8	138.9	182.6	224.8
GFSI	16.1	22.3	27.5	36.9	48.0	68.9	116.3
EMXI	**15.3**	25.7	34.4	44.3	67.0	71.2	82.8
NVGI	20.6	35.7	49.2	57.3	75.3	80.2	76.8
CMCI	18.2	24.7	26.0	**30.7**	**45.9**	54.5	77.2
GHMI	18.9	29.7	37.8	45.2	60.8	98.4	85.3
HWFI	16.8	21.6	25.7	**30.1**	50.7	89.6	116.8
CTCI	16.7	30.1	41.7	48.6	61.5	77.6	75.3
GFNI	24.6	42.5	60.3	73.6	105.9	180.5	220.2
TVCE	15.5	**20.4**	26.7	**30.3**	**35.1**	45.9	35.2
TVCX	**14.8**	**20.2**	**25.0**	**29.4**	**37.7**	46.6	38.5
GFEX	**14.3**	**20.8**	**24.2**	36.2	53.2	49.3	34.2
FSSE	**15.2**	**19.2**	**23.8**	**29.9**	**42.5**	59.9	64.4
AEMI	16.8	25.5	33.4	38.8	**44.3**	54.2	108.1
BAMS	32.8	63.3	98.8	121.6	147.1	205.3	294.7
BAMM	21.5	39.3	56.0	66.1	53.6	**36.9**	79.1
BAMD	20.1	33.9	51.9	71.1	95.8	139.5	284.5
Forecasts	20	19	17	16	12	8	4

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Estelle, 15-21 July 2016. 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	**4.0**	**6.6**	**9.5**	**13.3**	17.1	17.5	**13.3**
OCD5	4.0	6.0	6.0	6.3	3.5	7.6	6.8
Forecasts	24	22	20	18	14	10	6
OFCL (2011-15)	5.9	9.8	12.5	14.0	15.5	16.3	14.9
OCD5 (2011-15)	7.7	12.8	16.4	18.8	21.1	20.9	19.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Estelle, 15-21 July 2016. 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	4.3	7.6	10.3	14.1	16.7	17.5	12.5
OCD5	4.3	**6.1**	**6.4**	**5.8**	**3.4**	**7.4**	**6.8**
DSHP	4.3	**6.8**	**8.6**	**11.1**	**15.6**	20.0	19.0
LGEM	4.9	**7.0**	**7.2**	**7.9**	**6.3**	**3.9**	**3.3**
GHMI	**3.7**	**4.2**	**7.7**	**9.9**	**11.2**	**15.8**	17.5
HWFI	4.7	**5.8**	**5.4**	**5.8**	**8.3**	**12.8**	12.8
CTCI	5.1	**5.7**	**6.1**	**9.1**	**14.0**	**12.8**	**9.3**
GFNI	**3.7**	**4.8**	**5.7**	**6.4**	**7.6**	**12.8**	20.0
ICON	**4.0**	**5.4**	**5.9**	**7.1**	**8.8**	**12.3**	**12.3**
IVCN	**4.1**	**5.2**	**6.0**	**7.3**	**9.7**	**12.5**	**11.5**
FSSE	4.8	8.9	12.2	15.7	19.8	21.6	17.0
GFSI	4.8	**6.6**	**9.1**	**11.9**	**10.6**	**12.8**	16.0
EMXI	4.4	**7.3**	**9.4**	**9.8**	**10.7**	**11.8**	15.5
Forecasts	20	19	17	16	12	8	4

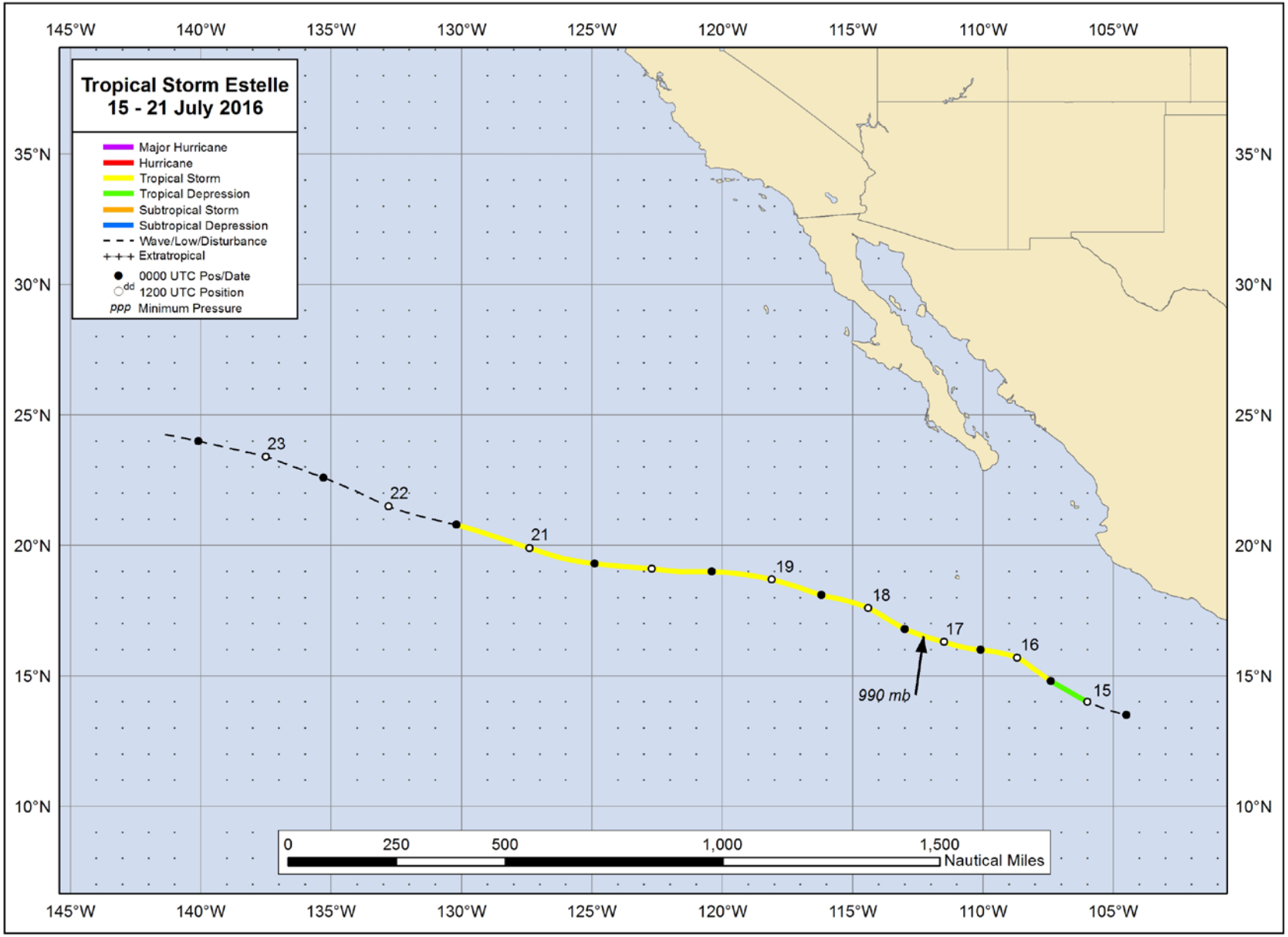

Figure 1. Best track positions for Tropical Storm Estelle, 15-21 July 2016.

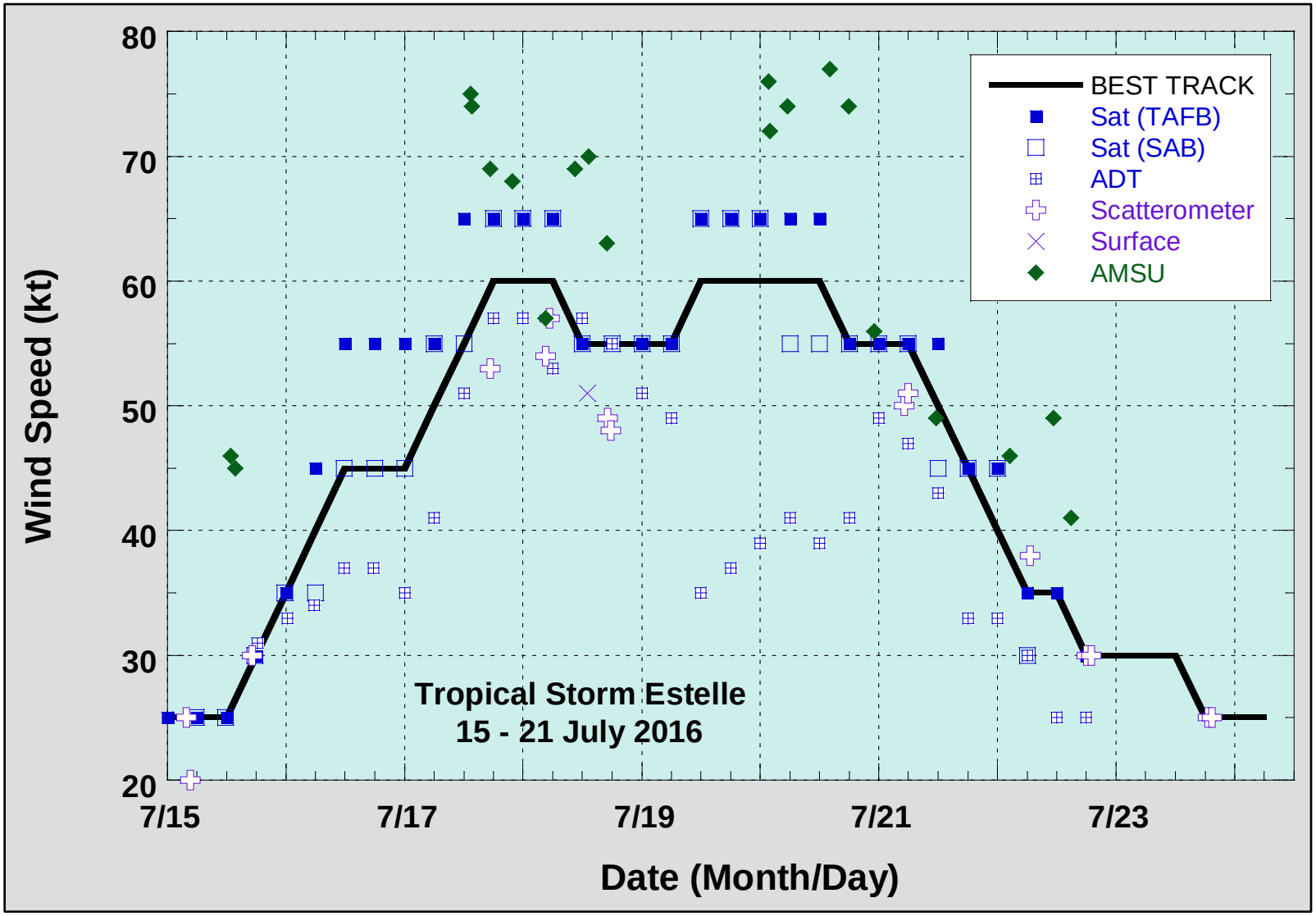

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Estelle, 15-21 July 2016. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

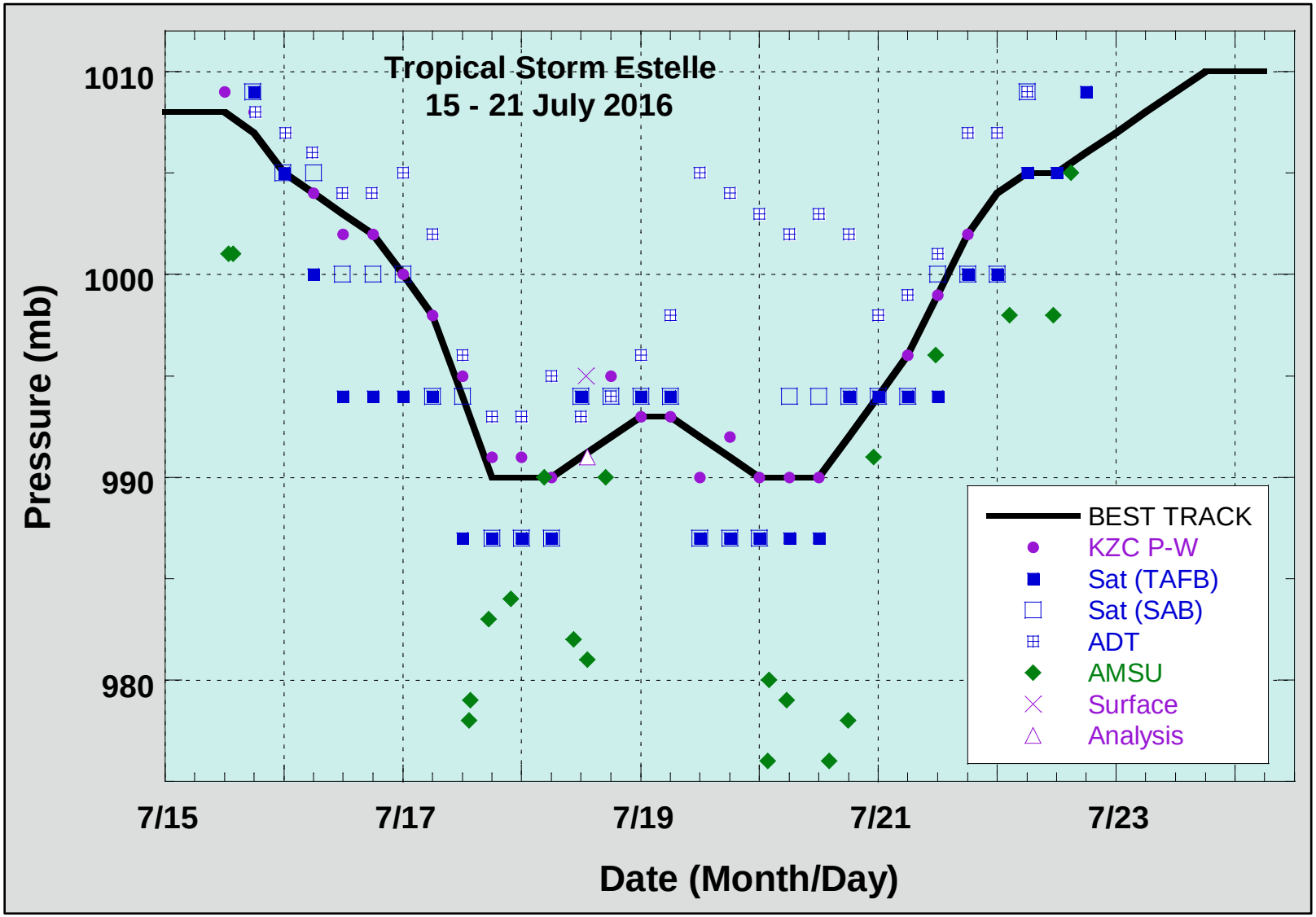

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Estelle, 15-21 July 2016. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological 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.

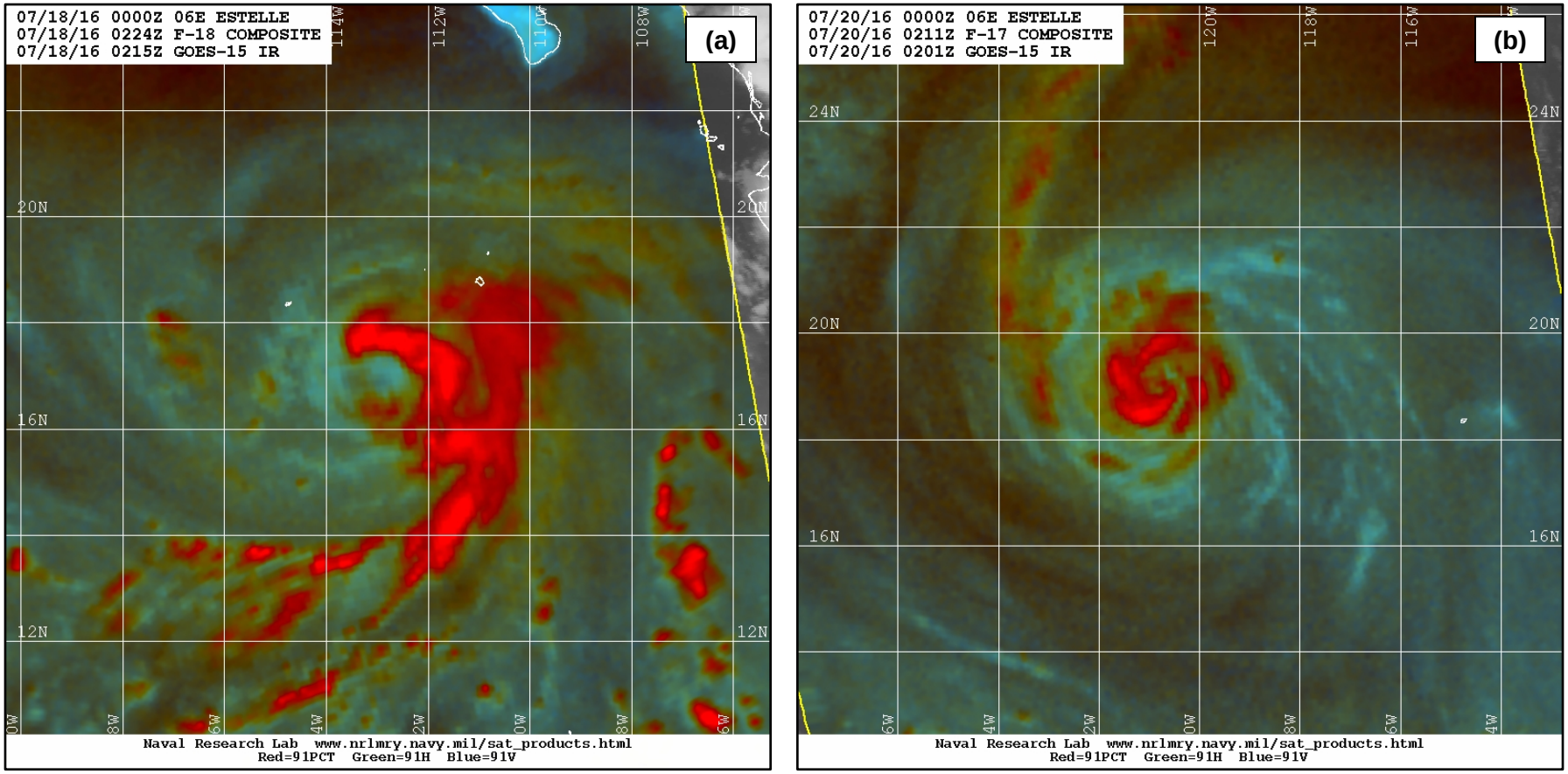

Figure 4. (a) 91-GHz SSMIS color composite microwave image of Tropical Storm Estelle at 0224 UTC 18 July 2016 when the cyclone was at its peak intensity for the first time. (b) 91-GHz SSMIS color composite microwave image of Estelle at 0211 UTC 20 July 2016 when the cyclone was at its peak intensity for the second time. Images courtesy of the Naval Research Laboratory.