NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM SEBASTIEN

(AL202019)

19–24 November 2019

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National Hurricane Center
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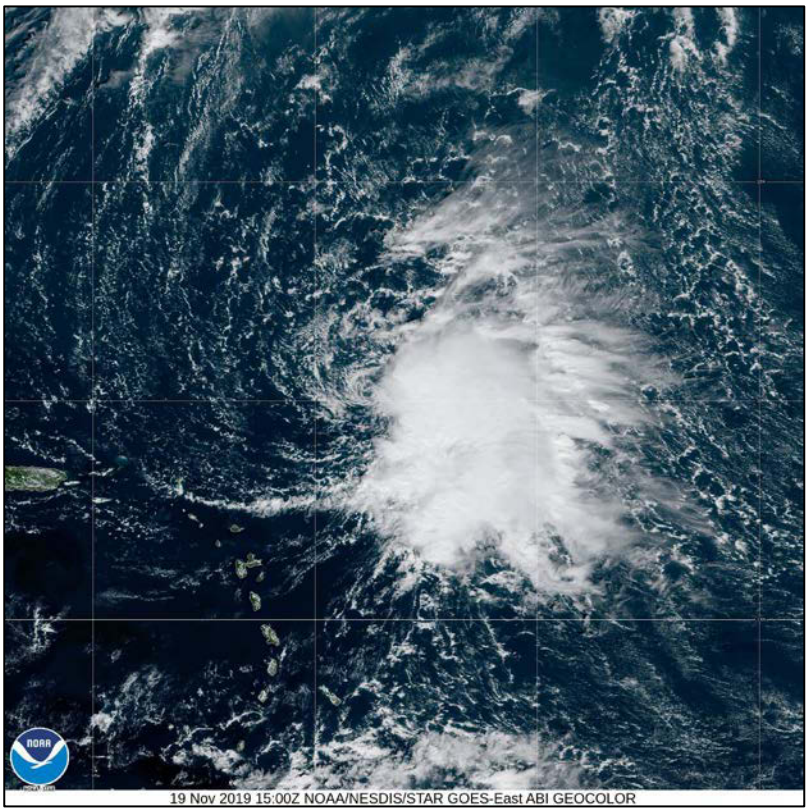

GOES-16 GEOCOLOR SATELLITE IMAGE OF TROPICAL STORM SEBASTIEN AT 1500 UTC 19 NOVEMBER 2019, SHORTLY AFTER THE TIME OF THE TROPICAL CYCLONE'S GENESIS.

Sebastien was a late-season tropical storm that formed northeast of the Leeward Islands, and then recurved over the central Atlantic Ocean. Sebastien became an extratropical cyclone while passing near the Azores, and it affected the British Isles before dissipating.

Tropical Storm Sebastien

19–24 NOVEMBER 2019

SYNOPTIC HISTORY

The complex late-season development of Sebastien appears to have been from primarily non-tropical origins. A series of mid- to upper-level troughs over the central subtropical Atlantic led to the development of a broad surface trough and large area of disorganized cloudiness and showers over the central Atlantic between roughly 15°–20°N and 45°–53°W during the middle of November. Although this activity may have been enhanced by the passage of a low-latitude tropical wave, a GFS-based Hovmöller diagram (not shown) of relative humidity and 800–600-mb vorticity is not suggestive of any significant influence from a tropical wave during that time period. On 15–16 November, the shower and thunderstorm activity continued to increase over the central Atlantic, which may have been aided by the passage of an eastward-moving convectively coupled Kelvin wave. As the disturbance moved west-northwestward, the surface trough sharpened and a broad area of low pressure formed several hundred n mi east of the Leeward Islands on 17 November. Although dry mid-level air and moderate northwesterly shear caused all of the shower and thunderstorm activity to be displaced over the eastern and southeastern portions of the circulation, the system gradually became better defined late on 18 November. Deep convection associated with the system markedly increased early the next day and the circulation became sufficiently well-defined shortly thereafter to result in the formation of a tropical storm by 0600 UTC 19 November when the system was located about 235 n mi northeast of the Leeward Islands. The "best track" chart of Sebastien'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].

Six hours after formation, Sebastien's intensity increased to 40 kt despite being located within an area of moderate to strong vertical wind shear that caused the circulation center to be exposed to the west of the deep convection (cover photo). At that time, the tropical storm was located near the southwestern portion of a subtropical ridge, which steered the system slowly west-northwestward during the next 24 h. Deep convection developed closer to Sebastien's center early on 20 November, resulting in some additional strengthening that day. By 1800 UTC 20 November, a mid- to upper-level trough and associated cold front moving over the southwestern Atlantic caused Sebastien to make an abrupt northward turn. Early the next day, the tropical storm turned northeastward ahead of the aforementioned trough.

While continuing to move northeastward on 21 November, a cold front began to impinge on the northwestern portion of Sebastien's circulation, which caused the circulation to become elongated, and a re-formation of the center may have occurred. Sebastien's center, however,

[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.

remained just east of the frontal boundary. Early on 22 November, Sebastien began to accelerate east-northeastward, and later that day, deep convection once again increased near and to the northeast of the low-level center. Sebastien strengthened and reached its estimated peak intensity of 60 kt by 0000 UTC 23 November.

Although the front was located very near the center of Sebastien and may have even wrapped around the southern portion of the circulation by the time the tropical storm reached its peak intensity (Fig. 4), the system maintained organized deep convection near its center. Despite the proximity of the nearby frontal zone, microwave satellite imagery (Fig. 5) on 23–24 November showed that Sebastien maintained tropical characteristics (e.g., organized convection and a low- to mid-level eye feature) while it accelerated northeastward. By late on 24 November, southwesterly vertical wind shear and significantly colder sea surface temperatures caused Sebastien to finally transition into an extratropical cyclone by 0000 UTC 25 November when the center passed near Flores Island in the westernmost Azores (Fig. 5).

The extratropical cyclone continued moving rapidly northeastward on 25 November and reached a second peak intensity of 60 kt by 0600 UTC 25 November. Although the cyclone continued to deepen, the wind field expanded and no further increase in peak wind speed occurred. The extratropical low began to weaken late on 25 November, and the forward motion slowed significantly when the system approached the southwestern coast of Ireland early on 26 November. The low moved over southwestern Ireland shortly after 0600 UTC that day. The cyclone, which was still producing gale-force winds, turned eastward while weakening, and then moved on a southeastward heading by late on 26 November. This motion brought the center of the low over the southern portion of the Irish Sea early on 27 November, and then over western England by 1200 UTC 27 November. The low's circulation became ill-defined shortly after that time, and the cyclone dissipated just west of London by 1800 UTC that day.

METEOROLOGICAL STATISTICS

Observations in Sebastien (Figs. 2 and 3) include subjective satellite-based Dvorak technique and Hebert-Poteat subtropical cyclone technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and Dvorak technique estimates from the Satellite Analysis Branch (SAB). Observations also include 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 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 Sebastien.

Ship reports of winds of tropical storm force associated with Sebastien are given in Table 2. The cruise ship *Crystal Serenity* (call sign C6SY3) reported tropical-storm-force winds at four different times on 19 November when the ship was located well to the east and southeast of Sebastien's center. The ship reported a peak wind speed of 43 kt at 1800 UTC that day, but these winds are likely unrepresentative of a 10-m surface wind due to the high elevation of the

ship's anemometer. NOAA buoy 41044 (21.6°N 48.6°W) reported a peak one-minute wind of 37 kt with a gust to 41 kt at 1549 UTC 21 November as Sebastian passed about 140 n mi northwest of the buoy. The buoy measured a minimum pressure of 1004.9 mb at 2110 UTC that day.

The estimated 60-kt peak intensity of Sebastien at 0000 and 0600 UTC 23 November is based on a pair of ASCAT passes that revealed peak winds of around 55 kt. One of the passes did not fully view the circulation, and although ASCAT-B did sample the entire wind field it is assumed that the coarse resolution of that instrument likely did not capture Sebastien's highest winds.

Although satellite and scatterometer data showed that Sebastien's circulation became elongated when the cyclone interacted with a cold front, the data suggest that the circulation remained intact and that the system maintained a center with enough definition for it to continue to be classified as a tropical cyclone on 21–23 November.

Sebastien moved near Flores Island in the westernmost Azores around the time that it transitioned into an extratropical low. The official observing site on the island reported a minimum pressure of 994.2 mb around 0000 UTC 25 November. The station did not report sustained winds of tropical storm strength. An unofficial site on the northern tip of the island near Ponta Delgada measured peak sustained winds of 37 kt with a gust to 48 kt, and a minimum pressure of 993.9 mb. The station also reported a temperature and dewpoint drop immediately following the passage of the center, further indicating that the system had become extratropical by that time. During Sebastien's post-tropical phase, buoy 62029 (48.7°N 12.4°W) reported a minimum pressure of 975.7 mb with winds of 20-kt at 0000 UTC 26 November when the center of the extratropical cyclone passed nearby.

Sebastien's extratropical remnants brought heavy rainfall and gale-force winds to Ireland and portions of the United Kingdom on 26–27 November. Selected surface observations from Ireland are listed in Table 3. The highest wind gust reported in Ireland was 48 kt at Roches Point in County Cork. Buoy 62107 (50.1°N 6.1°W) near southwestern England measured sustained winds of 42 kt at 0600 UTC 26 November, and several other ships and buoys located near southern England or in the English Channel reported gale-force winds on 26–27 November.

CASUALTY AND DAMAGE STATISTICS

The extratropical remnants of the system brought gale-force winds to Ireland and portions of the United Kingdom on 26–27 November, but there are no reports of damage or casualties associated with Sebastien.

FORECAST AND WARNING CRITIQUE

The genesis of Sebastien was not well anticipated. The disturbance from which Sebastien developed was introduced in the Tropical Weather Outlook only 66 h before formation occurred (Table 4). The 5-day genesis probabilities were initially in the low (<40%) category and were not raised into the medium (40–60%) category until 36 h before development occurred. The 5-day genesis potential in the Outlook did not reach the high (>60%) category until the time of genesis in the best track. The short-range (2-day) genesis forecasts also did not adequately anticipate the genesis of Sebastien. The system was assigned a 48-h medium chance of genesis only 30 h before development, and the short-range probabilities also did not reach the high category until the time of genesis.

A verification of NHC official track forecasts for Sebastien is given in Table 5a. Although Sebastien lasted more than 5 days as a tropical cyclone, the first six NHC forecasts predicted that the tropical cyclone would be absorbed by the approaching frontal zone within 72 h. As a result, there were only four verifying 72-h forecasts for Sebastien, and no verifying 96- or 120-h forecasts. The mean NHC forecast track errors for time periods for which official forecasts verified (12–72 h) are among the highest for any Atlantic basin tropical cyclone within the past 5–10 years. The average NHC 48-h and 72-h track errors for Sebastien were 295.2 (14 cases) and 339.6 n mi (4 cases), respectively. Those errors are 3.5 to more than 4.5 times greater than the 5-year means for those lead times. The OCD5 errors were nearly double their long-term means, suggesting the forecasts for Sebastien were more difficult than normal.

The NHC track forecast and the model guidance had tremendous difficulty in predicting the forward speed of Sebastien, which resulted in unusually large along-track errors (Fig. 6). The 48-h official forecasts during the first few days of Sebastien's existence were too fast in lifting the tropical storm northeastward, but forecasts issued on 22 November were far too slow (Fig. 7). The typically reliable ECMWF and GFS models exhibited extremely large biases, with the ECMWF having a slow bias and the GFS taking Sebastien northeastward much too quickly. The difficulty in predicting Sebastien's forward speed resulted in a total of nine NHC 48-h track errors of greater than 300 n mi, including one of 588 n mi. The 588 n mi 48-h track error is the largest two-day NHC track error within the past decade (Fig. 8) and is the largest 48-h NHC track error since 2003 (not shown). The TVCA multi-model consensus had an equally large error of 593 n mi for that same forecast cycle.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. The lowest mean track errors from 12 to 48 h were from the simple medium-layer trajectory and beta model (TABM). The ECMWF, GFS, and UKMET (EGRI) global models had errors that were about 3 to 6 times higher than their long-term means (Table 6). Since all of dynamical models struggled with the track forecast for Sebastien, the multi-model consensus aids also exhibited errors that were much larger than normal. The Florida State Superensemble (FSSE) had the lowest mean error at 72 h, but it was still 221.4 n mi. Although several of the individual models and consensus aids had lower mean errors than the NHC track forecasts at various lead times, the NHC track forecast errors were comparable with the TVCA multi-model consensus aid. This is not surprising since NHC typically relies on the multi-model aids when the track model spread is large, as was the case during Sebastien. The extremely large track errors

for Sebastien appear to be the result of the models not properly analyzing and maintaining the structure of Sebastien's vortex. The very large along-track errors of the later 48-h forecasts appear to be the result of the storm remaining stronger and more vertically deep than anticipated. The greater vertical depth of Sebastien resulted in a much faster northeastward motion ahead of the trough than predicted by all of the dynamical model guidance and the NHC forecast (Fig. 9).

Although the NHC forecasts initially did not indicate that Sebastien would survive more than a couple of days as a tropical cyclone, the intensity forecasts were somewhat better than the track forecasts (Table 7a). Official forecast intensity errors were generally comparable to 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 7b. The NHC intensity forecast errors were comparable to the best performing intensity aids at 12 and 24 h, and had the lowest mean errors of any intensity aid at 36 and 48 h, except for the OCD5 (climatology and persistence model) at 36 h. The regional hurricane models (HWRF and HMON) over-intensified the storm, with some of these model predictions showing Sebastien reaching category 2 hurricane strength. After initially predicting little intensification, the NHC forecasts on 21 November forecast Sebastien to become a hurricane within 24 to 36 h. Sebastien did strengthen during that time period but never reached hurricane strength.

There were no coastal tropical cyclone watches and warnings issued in association with Sebastien. Although Sebastien brought winds of tropical storm strength to portions of the Azores, non-tropical watches and warnings were issued for those islands by the Portuguese Institute for Sea and Atmosphere since Sebastien was forecast to become extratropical when it made its closest approach to those islands.

ACKNOWLEDGMENTS

Andrew Penny, James Franklin, and John Cangialosi assisted with statistics and figures related to Sebastien's track forecast verification. John Cangialosi also provided the best track map shown in Figure 1. The UKMET office provided a series of surface analyses that were helpful in analyzing Sebastien's post-tropical phase and Sandra Spilane of Met Éireann compiled peak wind and rainfall information for Ireland.

Table 1. Best track for Tropical Storm Sebastien, 19–24 November 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
19 / 0600	19.4	58.1	1006	35	tropical storm
19 / 1200	19.9	58.5	1004	40	"
19 / 1800	20.3	59.4	1004	40	"
20 / 0000	20.4	60.3	1002	40	"
20 / 0600	20.5	61.0	1000	45	"
20 / 1200	20.8	61.7	999	45	"
20 / 1800	21.3	61.7	999	45	"
21 / 0000	21.9	61.7	996	50	"
21 / 0600	22.4	61.4	996	50	"
21 / 1200	22.9	60.9	996	50	"
21 / 1800	23.5	60.1	996	50	"
22 / 0000	24.2	58.8	996	50	"
22 / 0600	24.5	57.3	996	50	"
22 / 1200	25.0	55.8	996	50	"
22 / 1800	25.8	54.4	994	55	"
23 / 0000	26.7	52.6	991	60	"
23 / 0600	28.1	50.5	991	60	"
23 / 1200	29.6	48.4	994	55	"
23 / 1800	31.5	46.4	994	55	"
24 / 0000	33.5	44.4	994	55	"
24 / 0600	35.2	41.7	994	55	"
24 / 1200	36.6	38.5	994	55	"
24 / 1800	38.2	34.7	994	55	"
25 / 0000	40.0	30.9	992	55	extratropical
25 / 0600	41.9	26.7	988	60	"
25 / 1200	44.0	22.0	982	60	"
25 / 1800	46.4	16.3	978	60	"
26 / 0000	48.8	12.2	974	55	"
26 / 0600	51.3	9.3	972	50	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
26 / 1200	52.2	9.3	970	45	"
26 / 1800	52.2	8.9	972	40	"
27 / 0000	51.8	8.2	974	40	"
27 / 0600	51.4	6.0	976	40	"
27 / 1200	51.3	2.1	980	40	"
27 / 1800					dissipated
23 / 0000	26.7	52.6	991	60	maximum wind and minimum pressure

Table 2. Selected ship reports with winds of at least 34 kt for Tropical Storm Sebastien and its extratropical cyclone phase. Note that some of the wind observations are taken from anemometers located well above the standard 10-m observation height.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
19 / 0200	C6SY3	20.8	53.5	120 / 35	1016.0
19 / 1200	C6SY3	19.6	56.0	140 / 35	1014.0
19 / 1800	C6SY3	18.8	57.6	160 / 43	1012.0
19 / 2100	C6SY3	18.5	58.3	170 / 35	1011.0
25 / 0000	A8OR8	37.8	31.1	290 / 38	1005.7
25 / 0300	VRFW5	39.3	25.3	180 / 41	1006.0
25 / 0900	HEWXGH	39.8	21.1	220 / 40	1006.4
26 / 0000	OXCH2	44.6	8.7	220 / 35	1002.7
26 / 0000	ZDNC2	44.6	8.7	230 / 40	1004.0
26 / 0000	3FNS5	46.3	8.5	200 / 38	993.5
26 / 0300	9HOF8	45.1	8.6	200 / 36	998.7
26 / 0400	ELZU2	45.4	8.1	230 / 44	999.7
26 / 1200	OXCH2	48.1	6.1	220 / 35	992.6
26 / 1200	EUCFR0	49.8	0.5	190 / 35	994.7
26 / 1300	EUCFR0	49.5	0.3	180 / 35	995.2
26 / 2000	EUCFR0	46.9	4.8	230 / 42	
26 / 2100	EUCFR0	47.2	4.9	240 / 41	988.4
26 / 2100	EUCFR1	47.5	3.8	230 / 39	987.1
26 / 2300	EUCFR0	47.9	5.1	240 / 37	
27 / 0400	ZCDW9	49.6	3.8	270 / 35	982.9
27 / 0700	EUCFR1	49.2	4.4	260 / 36	983.8
27 / 0900	EUCFR1	49.5	3.6	260 / 36	983.8
27 / 1100	EUCFR1	49.8	2.9	260 / 36	984.3
27 / 1200	BATFR0	49.8	0.5	250 / 49	983.4
27 / 1200	EUCFR1	49.9	2.5	260 / 39	984.5

Table 3. Selected surface observations from Ireland on 26 November 2019 during the passage of Sebastien's extratropical low.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press.[a] (mb)	Date/ time (UTC)[b]	Sustained (kt)[c]	Gust (kt)	
Roaches Point County Cork			26/1119	35	48	0.72
Malin Head County Donegal			26/1633	34	41	
Sherkin Island County Cork			26/0448	32	40	0.73
Mace Head County Galway			26/1132	30	42	
Cork Airport County Cork			26/0557	27	40	0.70
Valentia Observatory County Kerry						0.95

[a] Time is unknown.
[a] Date/time is for wind gust.
[c] Sustained wind averaging period is 10-minute.

Table 4. 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%)	54	66
Medium (40%-60%)	30	36
High (>60%)	-	-

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Sebastien, 19–24 November 2019. 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	55.5	124.4	208.3	295.2	339.6		
OCD5	71.6	168.7	301.0	409.4	867.7		
Forecasts	20	18	16	14	4		
OFCL (2014-18)	23.6	35.5	47.0	61.8	96.0	136.0	179.6
OCD5 (2014-18)	44.8	97.6	157.4	220.1	340.7	446.6	536.6

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Sebastien, 19–24 November 2019. 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	58.2	125.7	221.1	308.9	339.6		
OCD5	70.9	177.4	333.6	455.6	867.7		
GFSI	75.6	164.5	285.7	459.9	867.1		
HMNI	**55.2**	**121.1**	236.2	416.4	691.7		
HWFI	**56.2**	**110.3**	**217.3**	384.5	713.4		
EGRI	66.6	139.6	233.3	**301.8**	**222.2**		
EMXI	60.6	**119.4**	**198.3**	**273.6**	**281.1**		
CMCI	66.7	144.1	274.7	396.8	358.5		
NVGI	**55.3**	**103.1**	**187.2**	**281.3**	430.8		
AEMI	67.0	142.0	239.3	314.2	**262.0**		
HCCA	60.1	128.6	226.6	338.0	479.5		
FSSE	**55.8**	**112.4**	**201.8**	**285.6**	**221.4**		
TVCX	**58.0**	**120.4**	**209.6**	**291.5**	**322.8**		
GFEX	62.0	**124.5**	**220.2**	319.9	410.6		
TVCA	58.4	**123.4**	**217.4**	**300.6**	**337.4**		
TVDG	60.5	126.5	**220.6**	309.5	365.4		
TABD	**51.3**	**121.7**	239.9	441.0	1060.8		
TABM	**44.5**	**84.1**	**152.2**	**194.0**	412.2		
TABS	66.9	151.7	274.2	398.9	945.5		
Forecasts	14	14	12	10	4		

Table 6. Homogeneous comparison of selected global model track guidance and the official forecasts (n mi) for Tropical Storm Sebastien, 19–24 November 2019, and the 5-year (2014–2018) mean errors. Note that the errors of the NHC forecasts and the global models are much larger than their respectively long-term mean.

Forecast Period	NHC (OFCL)		Global Forecast System (GFSI)		European Centre (EMXI)		United Kingdom Met Office (EGRI)		Number of Forecasts	
	Sebastien	5-year mean	Sebastien	5-year mean	Sebastien	5-year mean	Sebastien	5-year mean	Sebastien	5-year mean
12	53.7	22.8	69.6	24.8	56.8	24.3	61.0	25.1	16	823
24	125.7	34.6	164.5	38.8	119.4	38.5	139.6	40.2	14	743
36	221.1	46.2	285.7	53.3	198.3	50.6	233.3	53.9	12	668
48	308.9	59.3	459.9	68.6	273.6	63.1	301.8	69.7	10	589
72	339.6	92.1	867.1	108.8	281.1	95.1	222.2	110.6	4	447
96		124.3		160.1		131.1		164.1		337
120		161.4		207.9		165.0		226.4		247

Table 7a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Sebastien, 19–24 November 2019. 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	**4.8**	8.1	**9.4**	**8.2**	15.0		
OCD5	4.0	5.7	7.7	8.2	9.0		
Forecasts	20	18	16	14	4		
OFCL (2014-18)	5.3	7.9	9.9	11.2	13.3	14.4	14.2
OCD5 (2014-18)	6.9	10.9	14.3	17.4	20.9	22.0	22.8

Table 7b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Sebastien, 19–24 November 2019, dates. 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 7a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	5.4	9.3	11.2	8.5	16.7		
OCD5	**3.5**	**5.6**	**7.8**	8.9	**10.0**		
GFSI	7.5	12.4	13.7	14.0	**14.7**		
HMNI	9.5	15.6	15.5	12.5	**16.0**		
HWFI	7.4	14.5	15.8	14.3	18.0		
EMXI	6.7	10.5	11.6	11.3	**13.7**		
HCCA	7.1	12.7	14.8	12.9	**14.7**		
FSSE	6.6	12.1	14.4	12.4	**14.0**		
DSHP	**5.1**	**8.9**	12.3	16.8	22.0		
LGEM	**5.0**	10.1	15.3	21.3	30.7		
ICON	**5.3**	9.9	12.2	11.6	21.3		
IVCN	6.4	11.1	13.3	11.3	19.0		
IVDR	7.3	12.1	14.2	11.9	16.7		
Forecasts	14	14	12	10	3		

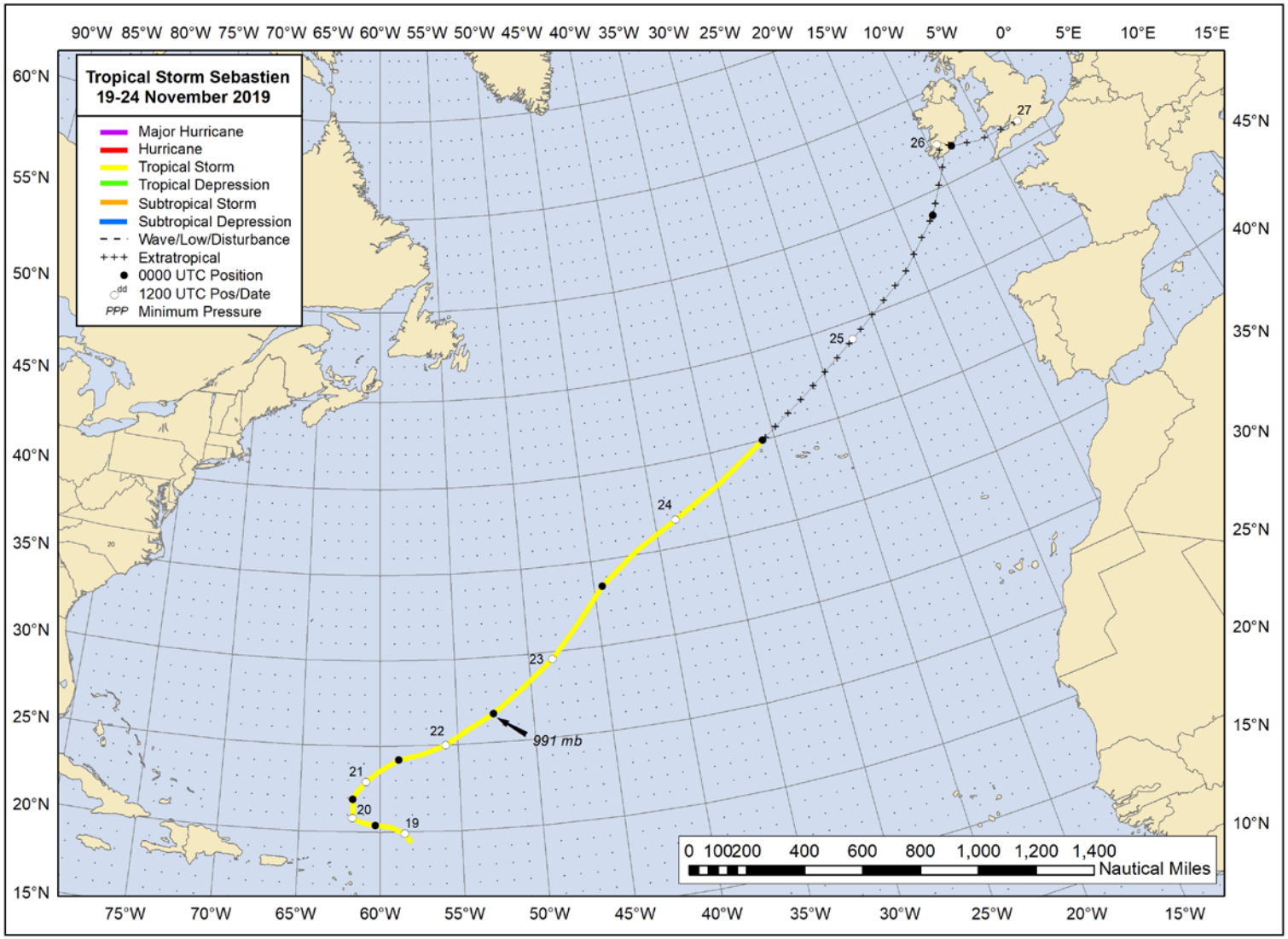

Figure 1. Best track positions for Tropical Storm Sebastien, 19–24 November 2019. The track during the extratropical stage is partially based on analyses from the United Kingdom Met Office.

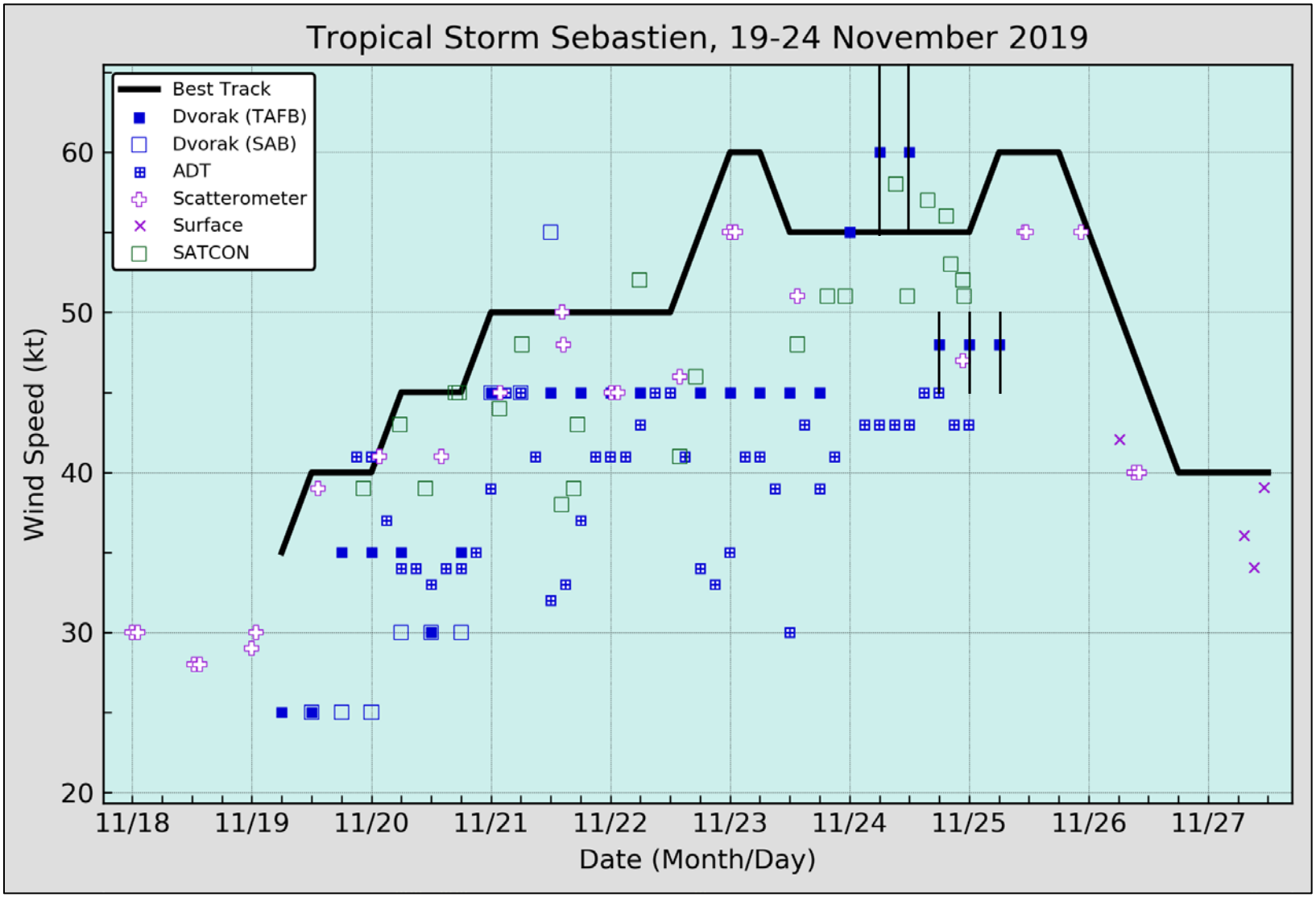

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Sebastien, 19–24 November 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC. Short solid lines depict intensity ranges associated with subtropical satellite classifications.

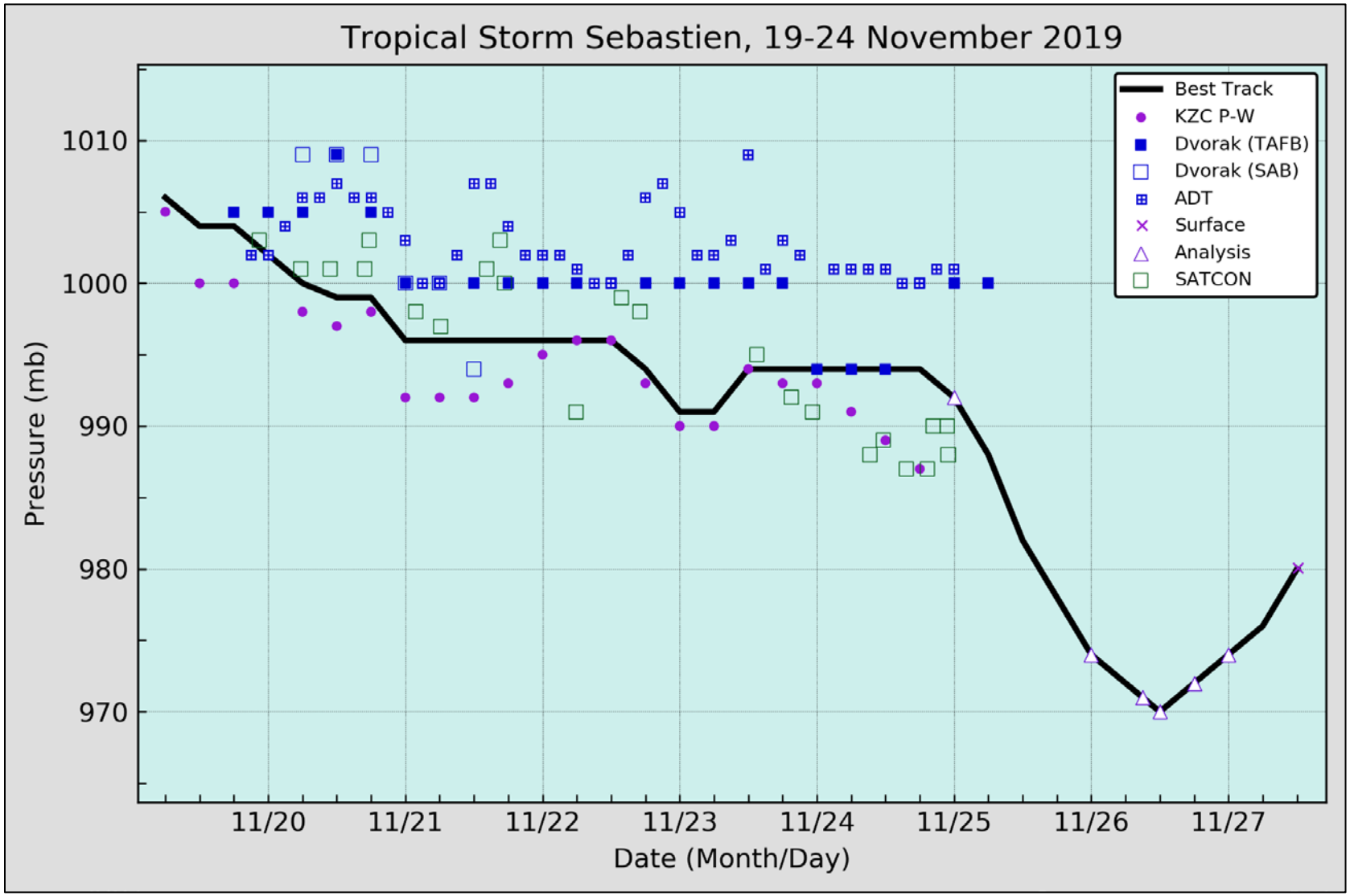

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Sebastien, 19–24 November 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute 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.

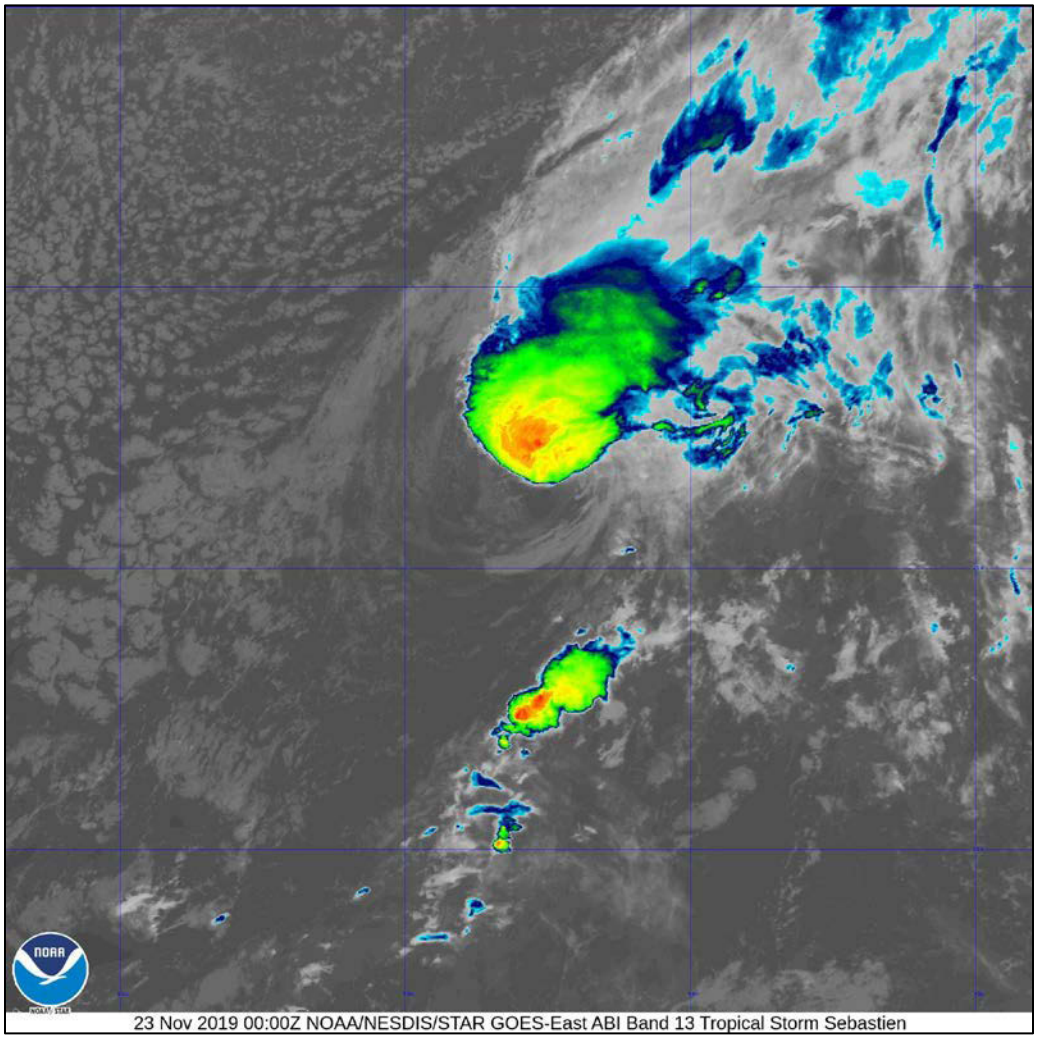

Figure 4. GOES-16 infrared satellite image of Tropical Storm Sebastian at 0000 UTC 23 November at the time of the tropical storm's peak intensity.

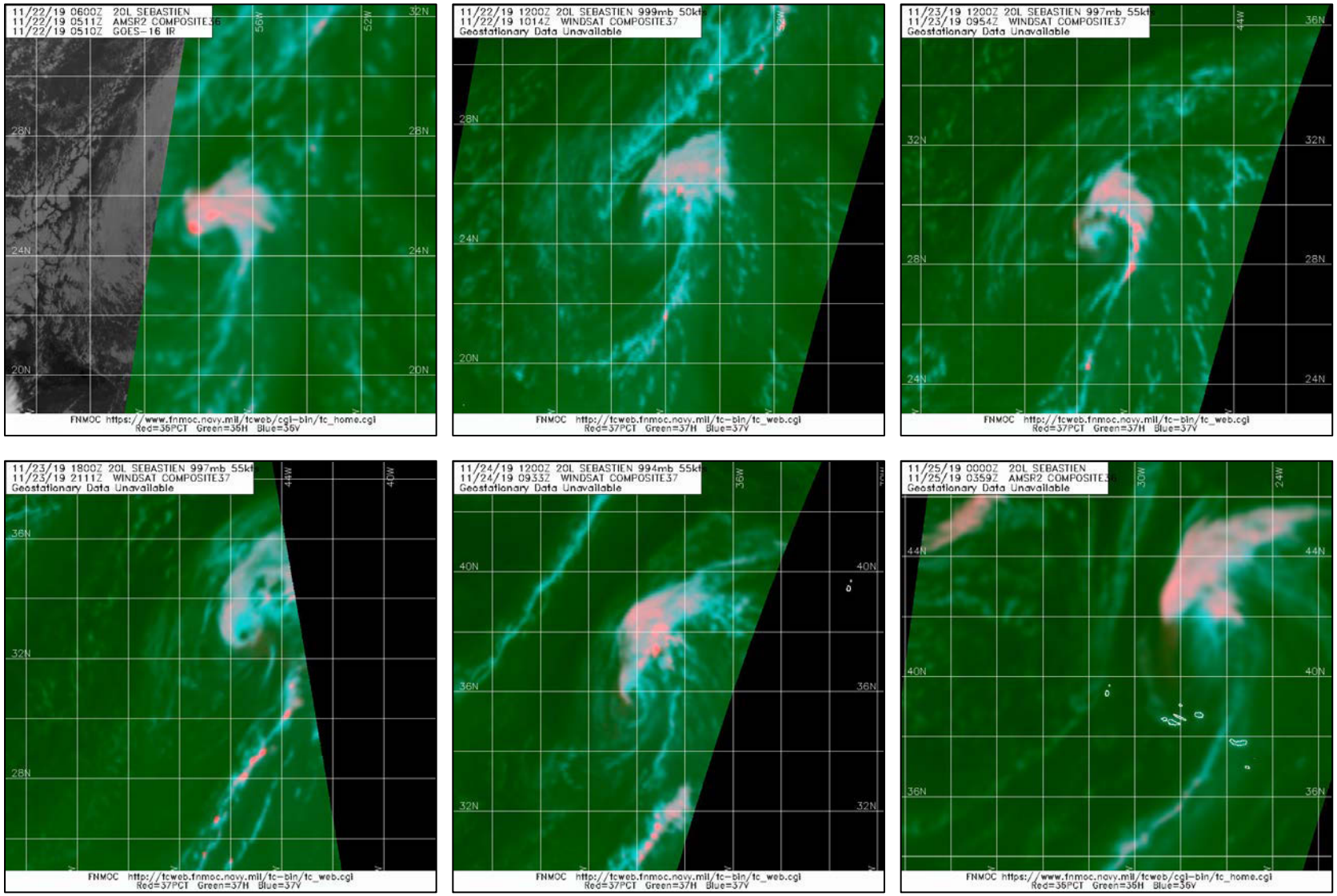

Figure 5. Series of 37-GHz microwave images of Tropical Storm Sebastien from 0511 UTC 22 November (upper left) to 0359 UTC 25 November (lower right). Note the presence of the inner-core features despite the cyclone's interaction with a frontal boundary during this time. The final image (lower right) shows the loss of this feature and notes the transition of the system into an extratropical cyclone.

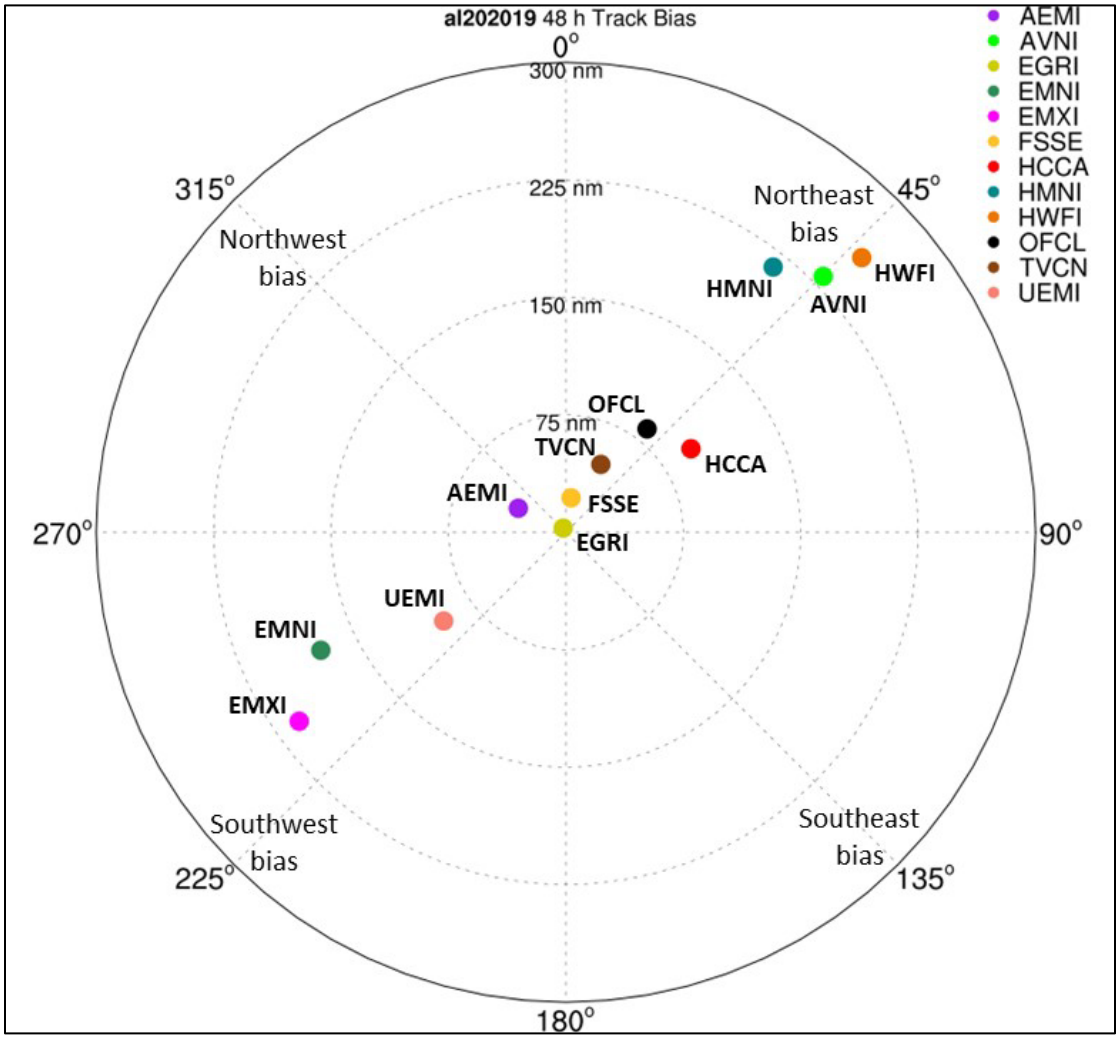

Figure 6. Polar diagram showing the mean bias (n mi) of the 48-h official forecasts (black dot) and selected track models. Despite a few forecasts exhibiting an extreme (southwestward) slow bias late in Sebastien's life, the mean NHC forecast bias was northeastward (too fast). Note the large biases of the ECMWF (EMXI) and GFS (AVNI). The UKMET (EGRI) and FSSE had the lowest 48-h track biases.

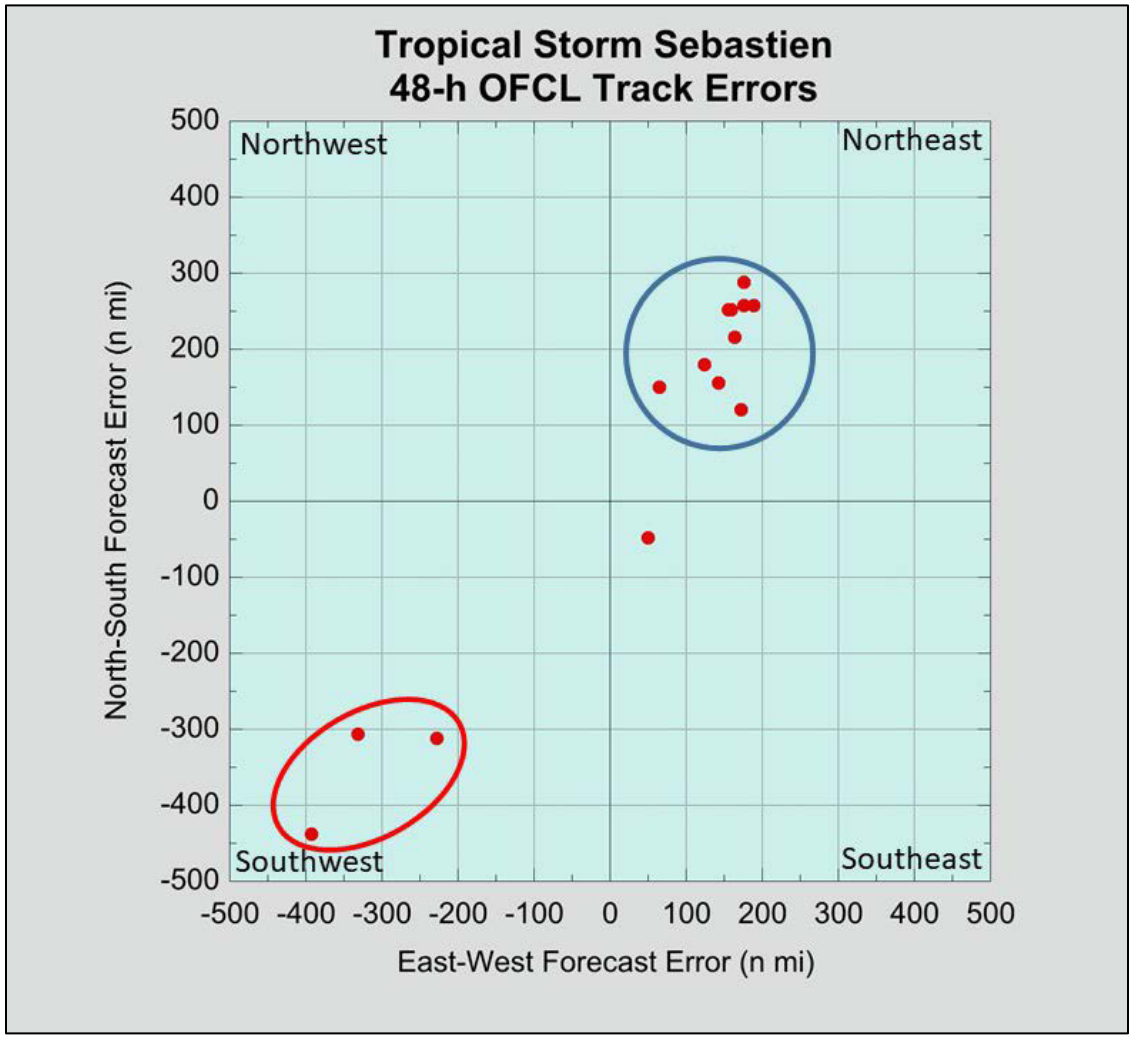

Figure 7. Plot showing the east-west and north-south error components (n mi) of all 14 of the verifying NHC 48-hour forecasts. Note the general northeastward (fast) bias of the NHC forecasts (blue circle) issued between Sebastien's genesis and 1800 UTC 21 November, and the large southwestern (slow) bias of the forecasts issued from 0600 UTC to 1800 UTC 22 November.

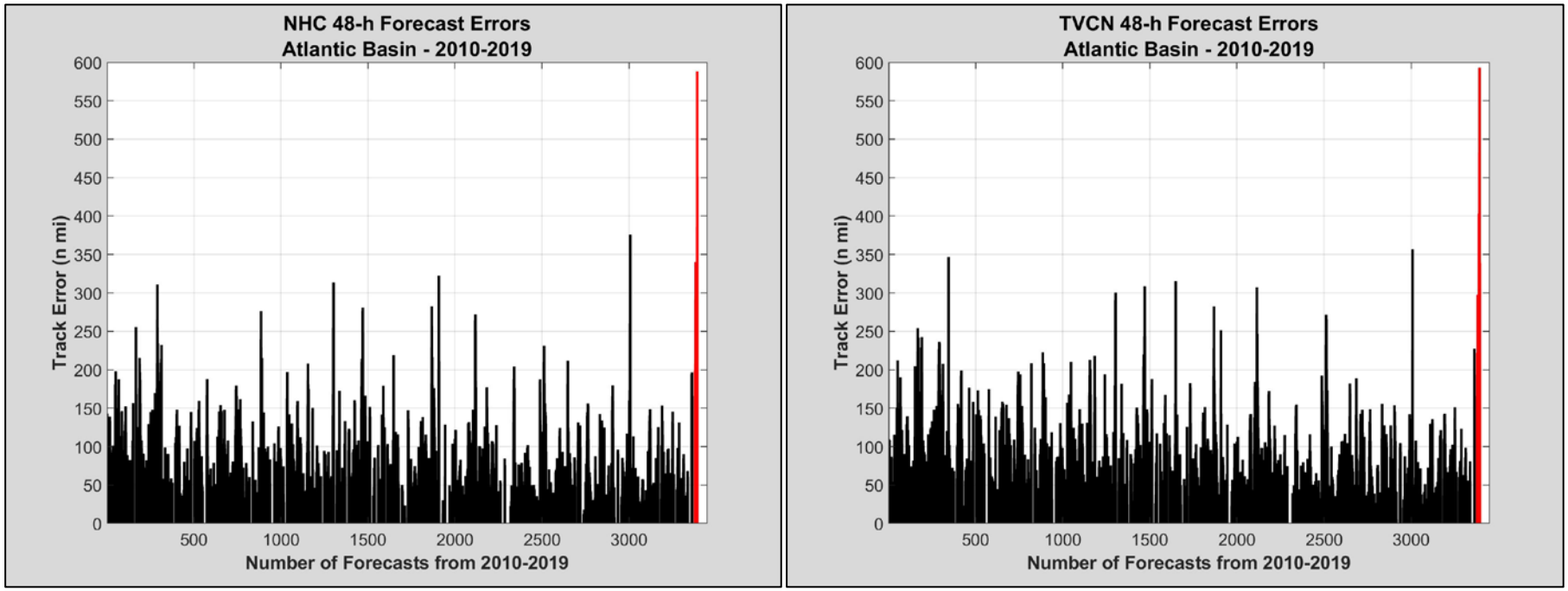

Figure 8. Histogram of NHC (left) and TVCA (right) 48-h track forecast errors (n mi) for the 10-year period from 2010-2019. Several of the 48-h NHC and TVCN forecasts for Sebastien had errors that were among the largest over that time period.

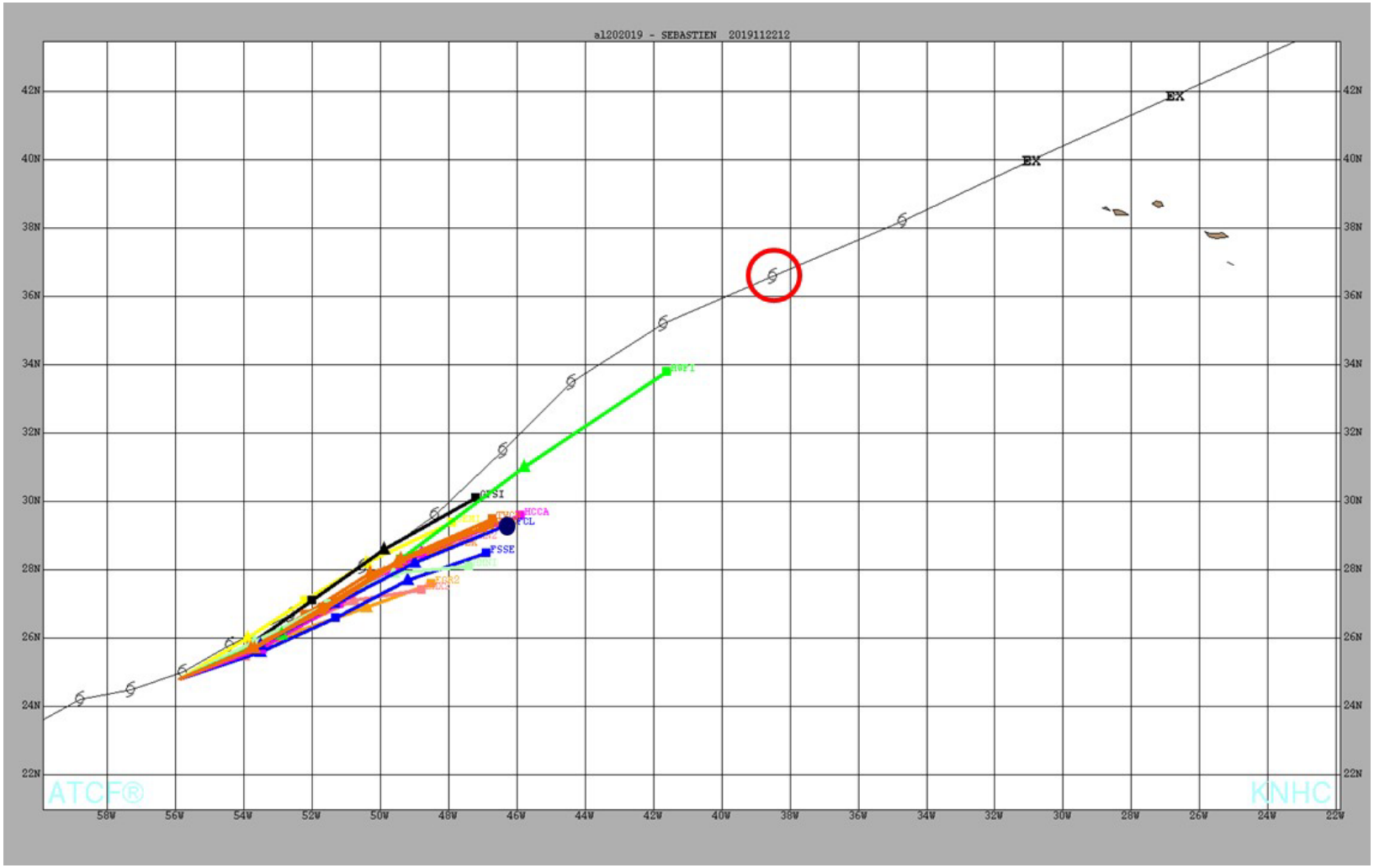

Figure 9. NHC 48-h track forecast (dark blue dot) and selected track model guidance at 1200 UTC 22 November. The verifying 48-h position of Sebastien is denoted by the red circle. All of the track models and the NHC forecast were too slow in taking Sebastien northeastward toward the Azores. This NHC forecast had a 48-h track error of 588 n mi, the highest since 2003. The TCVA multi-model consensus had an equally large track error of 593 n mi for this cycle.