NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE DANIELLE

(AL052022)

1 – 8 September 2022

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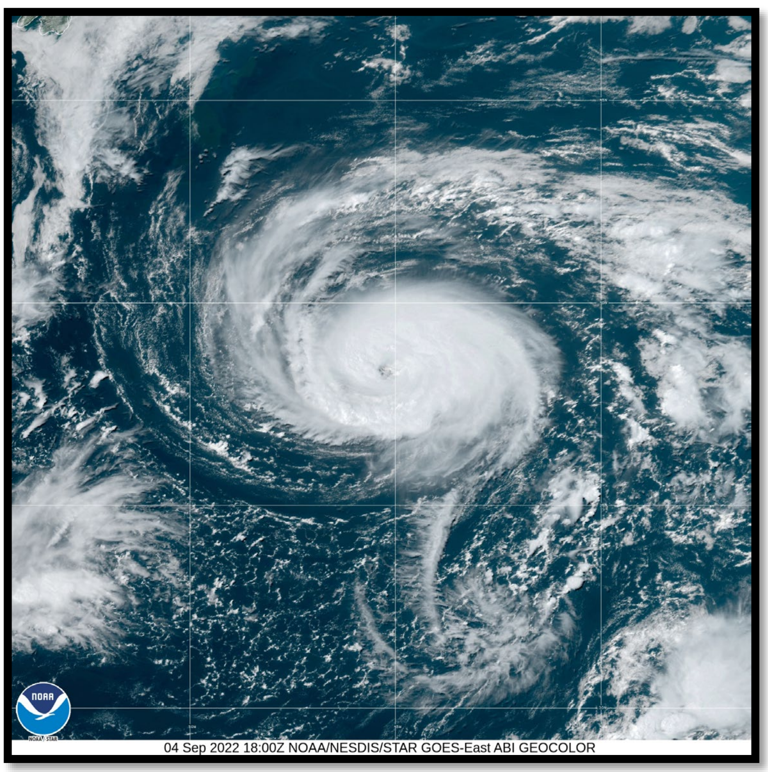
National Hurricane Center
25 January 2023



GOES-16 GEOCOLOR SATELLITE IMAGE OF HURRICANE DANIELLE AT 1800 UTC 4 SEPTEMBER 2022, AT THE TIME IT REACHED ITS PEAK INTENSITY (IMAGE COURTESY OF NOAA/NESDIS/STAR)

Danielle was a high-latitude category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that meandered over the north Atlantic Ocean for over two weeks as a tropical and extratropical cyclone. Danielle caused flooding and landslides in parts of Portugal while it was an extratropical cyclone.

Hurricane Danielle

1 – 8 SEPTEMBER 2022

SYNOPTIC HISTORY

Danielle had non-tropical origins, forming from a frontal boundary that stalled over the north Atlantic Ocean on 29 August where the warm Gulf Stream ocean current branches off into the Azores Current. The thermal gradient north of the frontal boundary weakened during the next couple of days, and a low pressure system developed along the remnant trough by 1200 UTC 31 August. Convective banding formed fairly quickly on the eastern side of the low and began wrapping around the center early on 1 September (Fig. 1a), leading to the formation of a tropical depression by 0600 UTC while located about 620 n mi southeast of Cape Race, Newfoundland. The depression immediately began a 30-h period of rapid intensification (RI) and became a hurricane by 1200 UTC 2 September (Fig. 1b) when it was located about 590 n mi west of Flores Island in the Azores. The "best track" chart of Danielle's path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[1].

Danielle's RI at such a high latitude over the north Atlantic is a rare occurrence and was likely aided by warmer-than-normal (+2–3°C) sea surface temperatures of about 27–28°C (Fig. 5), cold temperatures in the upper troposphere, and low deep-layer vertical wind shear. Danielle meandered in the same general area during its period of RI due to being embedded within a Rex blocking pattern, and as shown in Fig. 5, the hurricane upwelled waters cooler than 26°C. As a result, deep convection waned (Fig. 1c), and Danielle weakened back to a tropical storm by 0600 UTC 3 September. Through the day, the blocking high to the north caused Danielle to drift westward and escape its cold wake, and the storm re-strengthened to a hurricane by 0000 UTC 4 September. Strengthening continued due to low shear and relatively warm ocean waters, and Danielle reached its estimated peak intensity of 75 kt by 1800 UTC that day while located about 660 n mi west of Flores Island (cover photo and Fig. 1d).

The Rex block dissipated by 5 September, and slightly stronger mid-latitude flow caused Danielle to begin moving faster toward the northeast, which continued for the next several days. Although Danielle maintained hurricane intensity during that time, the central core region and radius of maximum winds expanded significantly (Fig. 1e). Deep-layer shear began to increase late on 7 September and caused Danielle to weaken to a tropical storm by 0600 UTC 8 September (Fig. 1f). Just 6 h later, Danielle became an extratropical cyclone about 470 n mi north of Flores Island as it became embedded within a frontal zone and developed a classic comma-shaped upper-level cloud shield.

[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 extratropical cyclone occluded while making a counterclockwise loop over the north Atlantic from 8 through 10 September while interacting with a deep-layer low moving eastward from Atlantic Canada. The occluded low gradually weakened while moving eastward and southeastward to the north of the Azores from 10 through 12 September. For several more days, the system meandered and looped off the coasts of Portugal and northwestern Spain, and the surface circulation finally dissipated about 100 n mi north-northwest of Lisbon, Portugal, late on 15 September.

METEOROLOGICAL STATISTICS

Observations in Danielle (Figs. 3 and 4) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and 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 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 Danielle.

Danielle's estimated peak intensity of 75 kt from 1800 UTC 4 September to 1800 UTC 5 September is based on a blend of subjective satellite intensity estimates of T4.5/77 kt from TAFB and SAB, and objective ADT and SATCON estimates as high as 72 kt. The estimated minimum pressure of 972 mb is based on a blend of output from the Knaff-Zehr-Courtney (KZC) pressure-wind relationship and SATCON estimates. ADT estimates had a notable low bias beginning on 5 September when Danielle's circulation and convective pattern broadened. However, UW-CIMSS's newer Artificial Intelligence Advanced Dvorak Technique (AiDT)[2] yielded values much closer to the other estimates (not shown in Fig. 3).

There were no ship reports of winds of tropical storm force associated with Danielle.

CASUALTY AND DAMAGE STATISTICS

Near the end of its life as an extratropical cyclone, Danielle caused damage in parts of Portugal due to flooding and landslides. Beginning on 12 September, heavy rains fell on burn scar areas of the Serra da Estrela mountain range, where devastating forest fires had occurred during the summer. Floodwaters, mud, downed trees, and debris flowed down hillsides near the village of Sameiro, damaging buildings and infrastructure, and dragging at least four vehicles into the Zêzere River. The Portuguese Institute of Sea and Atmosphere (IPMA) reported that

[2] Olander, Timothy, Anthony Wimmers, Christopher Velden, and James P. Kossin. "Investigation of Machine Learning Using Satellite-Based Advanced Dvorak Technique Analysis Parameters to Estimate Tropical Cyclone Intensity". Weather and Forecasting 36.6 (2021): 2161-2186. < https://doi.org/10.1175/WAF-D-20-0234.1>. Web. 7 Dec. 2022.

3.30 inches (83.7 mm) of rain had fallen in the city of Guarda in 24 h.[3] Flooding also occurred in other parts of the country, including within the Lisbon metropolitan area.

FORECAST AND WARNING CRITIQUE

Danielle's genesis was poorly forecast, particularly for a cyclone that went on to become a hurricane only 30 h after it formed. Table 2 provides the number of hours in advance of formation with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. A low (<40%) chance of genesis during the next 2 and 5 days was first indicated in the TWO at 0000 UTC 31 August, only 30 h before Danielle formed. The 2-day chance of genesis was raised to medium (40-60%) 18 h before genesis and to high (>60%) 12 h before formation. Figure 6 shows that Danielle's location of genesis fell within all of the potential genesis areas depicted in NHC's Graphical Tropical Weather Outlook, largely because of the short lead times. A significant part of the failure to predict genesis was due to global models showing little to no development in the days prior to Danielle's formation. As shown in Fig. 7, the 0000 UTC 30 August runs of the GFS, ECMWF, UKMET, and Canadian models only showed a weak low, at best, 84 h later at the valid time when Danielle is estimated to have become a hurricane. The reason for the models' unanimously poor simulation of Danielle's formation and subsequent intensification is unknown at this time.

A verification of NHC official track forecasts for Danielle is given in Table 3a. Official track forecast errors were lower than the mean official errors for the previous 5-year period at all forecast times, and even the 5-day average forecast error was less than 60 n mi. These low errors should not be too surprising given that Danielle moved very little, and was forecast to move very little, during its time as a tropical cyclone (the long extratropical phase is not included in the verification procedure).

A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b and Fig. 8. The best-performing deterministic model, and the only one that consistently outperformed the NHC official forecasts (at least through 72 h) was the GFS. The fixed and variable simple consensus models (GFEX, TVCA, TVCX, and TVDG) also performed well and had lower errors than the official forecasts through 72 h. The 4- and 5-day official forecasts were quite good, having lower errors than nearly all of the available guidance.

A verification of NHC official intensity forecasts for Danielle is given in Table 4a. Official intensity errors were lower than the mean official errors for the previous 5-year period at all forecast times. Climatology-persistence (OCD5) errors were lower than their respective 5-year means at all forecast times, suggesting that Danielle's intensity was less difficult to forecast than for a typical Atlantic tropical cyclone over the past 5 years.

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[3] Davies, Richard. "Portugal – Floods and Landslides Cause Severe Damage in Manteigas." *FloodList*, 14 Sept. 2022, https://floodlist.com/europe/portugal-floods-manteigas-september-2022.

A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b and Fig. 9. Even though the NHC official intensity errors were low, several models had even lower errors. The GFS and HMON (HMNI) performed well, as did the various simple intensity consensus models (ICON, IVCN, and IVDR). The Decay-SHIPS model (DSHP) was a notable outlier. Whereas most models had average intensity errors of 10 kt or less through the entire 5-day forecast period, DSHP had average intensity errors as large as 26 kt at days 4 and 5. This model appears to have had a significant high bias, with several runs incorrectly suggesting that Danielle could reach major hurricane intensity.

There were no coastal watches or warnings issued in association with Danielle.

ACKNOWLEDGMENTS

Philippe Papin of the NHC Hurricane Specialist Unit is thanked for creating the sea surface temperature maps in Fig. 5.

Table 1. Best track for Hurricane Danielle, 1–8 September 2022.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
31 / 1200	37.5	46.6	1016	25	low
31 / 1800	37.8	46.1	1015	25	"
01 / 0000	38.0	45.6	1014	25	"
01 / 0600	38.1	45.2	1011	30	tropical depression
01 / 1200	38.1	44.8	1007	35	tropical storm
01 / 1800	38.0	44.4	1002	45	"
02 / 0000	37.9	44.1	996	55	"
02 / 0600	37.8	43.8	990	60	"
02 / 1200	37.8	43.6	986	65	hurricane
02 / 1800	37.9	43.5	985	65	"
03 / 0000	38.0	43.6	986	65	"
03 / 0600	38.0	43.8	989	60	tropical storm
03 / 1200	38.0	44.2	989	60	"
03 / 1800	38.0	44.6	989	60	"
04 / 0000	37.9	45.0	986	65	hurricane
04 / 0600	37.9	45.3	982	70	"
04 / 1200	38.1	45.4	979	70	"
04 / 1800	38.4	45.2	976	75	"
05 / 0000	38.7	45.0	975	75	"
05 / 0600	39.2	44.6	975	75	"
05 / 1200	39.9	44.1	975	75	"
05 / 1800	40.6	43.6	976	75	"
06 / 0000	41.3	43.1	980	70	"
06 / 0600	41.8	42.5	982	65	"
06 / 1200	42.1	41.8	982	65	"
06 / 1800	42.3	41.0	980	65	"
07 / 0000	42.5	39.9	978	65	"
07 / 0600	42.9	38.6	974	70	"
07 / 1200	43.5	37.2	972	70	"
07 / 1800	44.4	35.6	972	70	"
08 / 0000	45.3	33.9	973	65	"
08 / 0600	46.2	32.4	974	60	tropical storm

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
08 / 1200	47.3	31.4	975	55	extratropical
08 / 1800	48.5	30.8	975	55	"
09 / 0000	49.8	30.5	975	55	"
09 / 0600	51.0	31.1	976	50	"
09 / 1200	51.1	33.2	977	50	"
09 / 1800	49.8	34.8	979	45	"
10 / 0000	47.8	34.1	983	45	"
10 / 0600	46.1	31.2	985	45	"
10 / 1200	45.2	28.0	987	40	"
10 / 1800	44.7	26.1	988	40	"
11 / 0000	43.9	24.7	990	40	"
11 / 0600	42.7	23.4	991	35	"
11 / 1200	41.2	21.9	992	35	"
11 / 1800	40.1	20.4	993	35	"
12 / 0000	39.1	18.8	994	35	"
12 / 0600	38.4	17.0	994	35	"
12 / 1200	38.6	15.0	994	35	"
12 / 1800	39.4	12.7	993	35	"
13 / 0000	40.8	11.2	992	35	"
13 / 0600	42.5	10.6	992	35	"
13 / 1200	43.3	10.7	993	35	"
13 / 1800	43.6	11.3	994	35	"
14 / 0000	43.3	11.4	996	30	"
14 / 0600	43.0	11.2	998	25	"
14 / 1200	42.7	10.9	1000	25	"
14 / 1800	42.5	10.4	1003	25	"
15 / 0000	42.2	10.1	1006	25	"
15 / 0600	41.6	10.0	1008	25	"
15 / 1200	40.9	10.1	1010	20	"
15 / 1800	40.2	10.3	1012	20	"
16 / 0000					dissipated
04 / 1800	38.4	45.2	976	75	maximum winds
07 / 1200	43.5	37.2	972	70	minimum pressure

Table 2. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) 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	30
Medium (40%-60%)	18	24
High (>60%)	12	18

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Danielle, 1–8 September 2022. 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	60	72	96	120
OFCL	**13.0**	**23.0**	**26.8**	**25.4**	**30.1**	**41.4**	**49.8**	**58.4**
OCD5	37.0	85.0	123.6	158.5	188.3	238.3	267.2	217.9
Forecasts	27	25	23	21	19	17	13	9
OFCL (2017-21)	23.6	35.5	47.6	61.4	78.2	91.3	125.6	172.1
OCD5 (2017-21)	45.5	98.3	156.7	213.7	252.4	316.9	403.6	484.6

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Danielle, 1–8 September 2022. 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	60	72	96	120
OFCL	11.9	22.0	27.0	27.6	32.1	43.6	53.9	70.9
OCD5	38.6	87.3	125.0	157.0	180.7	228.4	259.8	177.5
GFSI	**11.6**	**20.3**	**24.6**	**27.3**	**25.9**	**33.9**	69.2	142.9
EMXI	12.4	**20.6**	28.7	36.4	38.0	47.2	74.5	124.6
EGRI	12.5	23.8	31.1	35.0	45.1	59.3	89.8	144.5
CMCI	12.9	24.3	30.8	35.6	32.7	**43.4**	75.9	159.1
NVGI	17.3	35.2	49.5	67.1	75.8	85.5	140.4	146.4
HWFI	14.3	23.9	27.3	**27.3**	34.2	43.6	64.9	103.4
HMNI	14.8	22.1	**25.1**	28.3	34.7	47.0	67.7	151.6
CTCI	13.6	**21.7**	28.8	37.1	49.5	64.9	90.6	117.8
AEMI	12.0	**21.2**	**26.2**	30.3	**31.1**	**37.4**	**43.2**	79.9
HCCA	**10.5**	**20.3**	**26.7**	30.6	39.1	51.0	64.8	84.6
FSSE	**11.0**	**19.8**	29.7	34.8	40.1	51.4	67.1	93.3
GFEX	**11.1**	**18.7**	**23.5**	**24.9**	**29.0**	**38.3**	66.1	112.7
TVCA	**11.2**	**19.6**	**25.0**	**25.3**	**30.9**	**40.1**	57.4	78.3
TVCX	**11.2**	**19.0**	**24.4**	**24.5**	**30.8**	**38.9**	59.2	78.6
TVDG	**11.6**	**19.8**	**24.7**	**24.8**	**29.8**	**38.0**	59.9	82.5
TABD	25.6	62.1	102.8	142.7	172.9	202.0	322.7	753.4
TABM	18.1	38.2	63.9	87.4	102.5	105.6	126.6	230.7
TABS	20.8	34.8	51.2	61.7	65.5	63.6	82.1	149.4
Forecasts	23	21	19	18	16	14	10	7

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Danielle, 1–8 September 2022. 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	60	72	96	120
OFCL	**3.5**	**6.4**	**7.0**	**6.4**	**6.1**	**5.0**	**5.8**	**6.1**
OCD5	4.8	8.2	9.5	8.0	6.3	5.1	3.3	9.8
Forecasts	27	25	23	21	19	17	13	9
OFCL (2017-21)	5.4	8.0	9.5	10.9	11.0	12.1	13.1	14.7
OCD5 (2017-21)	7.0	11.1	14.5	17.1	18.0	20.2	21.9	22.1

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Danielle, 1–8 September 2022. 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	60	72	96	120
OFCL	2.6	5.5	7.1	6.9	5.9	5.0	6.0	5.0
OCD5	3.8	6.6	8.9	8.1	6.4	5.1	**3.6**	9.4
HWFI	5.6	**5.2**	7.3	7.5	6.6	5.6	7.5	9.0
HMNI	2.9	**4.4**	**6.4**	7.5	**5.2**	**4.1**	**5.9**	8.4
CTCI	4.7	7.4	7.6	8.2	8.9	8.6	10.0	5.6
DSHP	3.8	7.4	11.0	14.0	18.1	21.8	26.6	26.4
LGEM	4.0	6.5	8.5	9.0	8.0	7.7	**5.0**	**3.6**
ICON	2.8	**5.0**	**6.7**	**6.4**	6.8	8.3	9.1	6.1
IVCN	3.0	**4.9**	**6.2**	**6.0**	**5.0**	5.3	6.7	**4.0**
IVDR	3.1	**4.8**	**6.3**	**5.6**	**4.2**	**3.1**	**5.8**	**2.4**
HCCA	3.3	6.3	7.5	6.9	6.4	6.6	6.2	**3.1**
FSSE	3.2	5.7	7.6	8.3	7.9	7.4	6.4	**4.1**
GFSI	4.6	6.5	7.1	**5.4**	**4.3**	**3.6**	**3.8**	**3.4**
EMXI	4.8	7.4	7.7	7.4	8.5	9.3	9.6	12.0
Forecasts	23	21	19	18	16	14	10	7

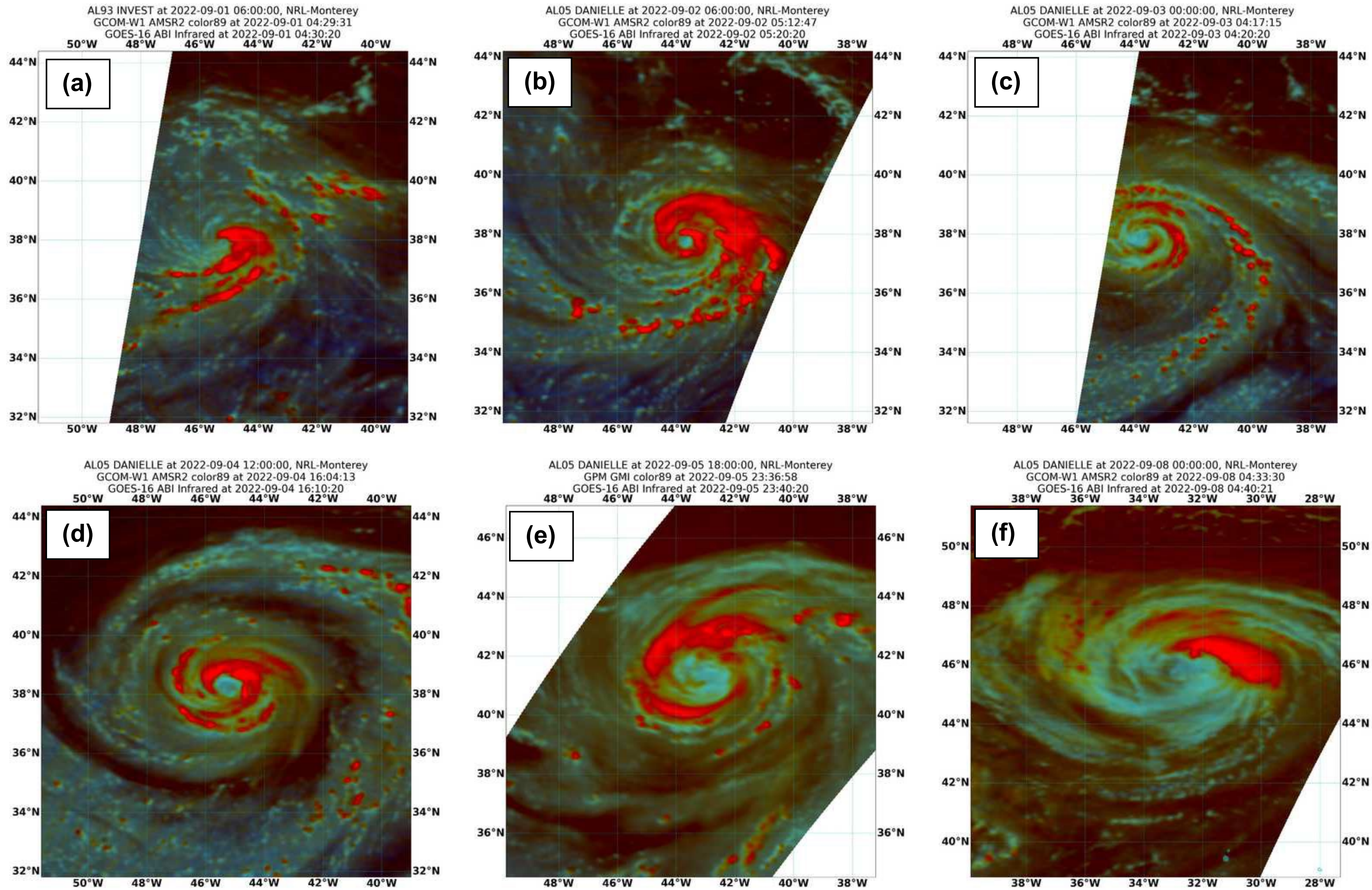

Figure 1. Series of 89-GHz GCOM-W1 AMSR2 and GMI microwave images showing the convective evolution of Hurricane Danielle from 1–8 September. Images courtesy of the Naval Research Laboratory.

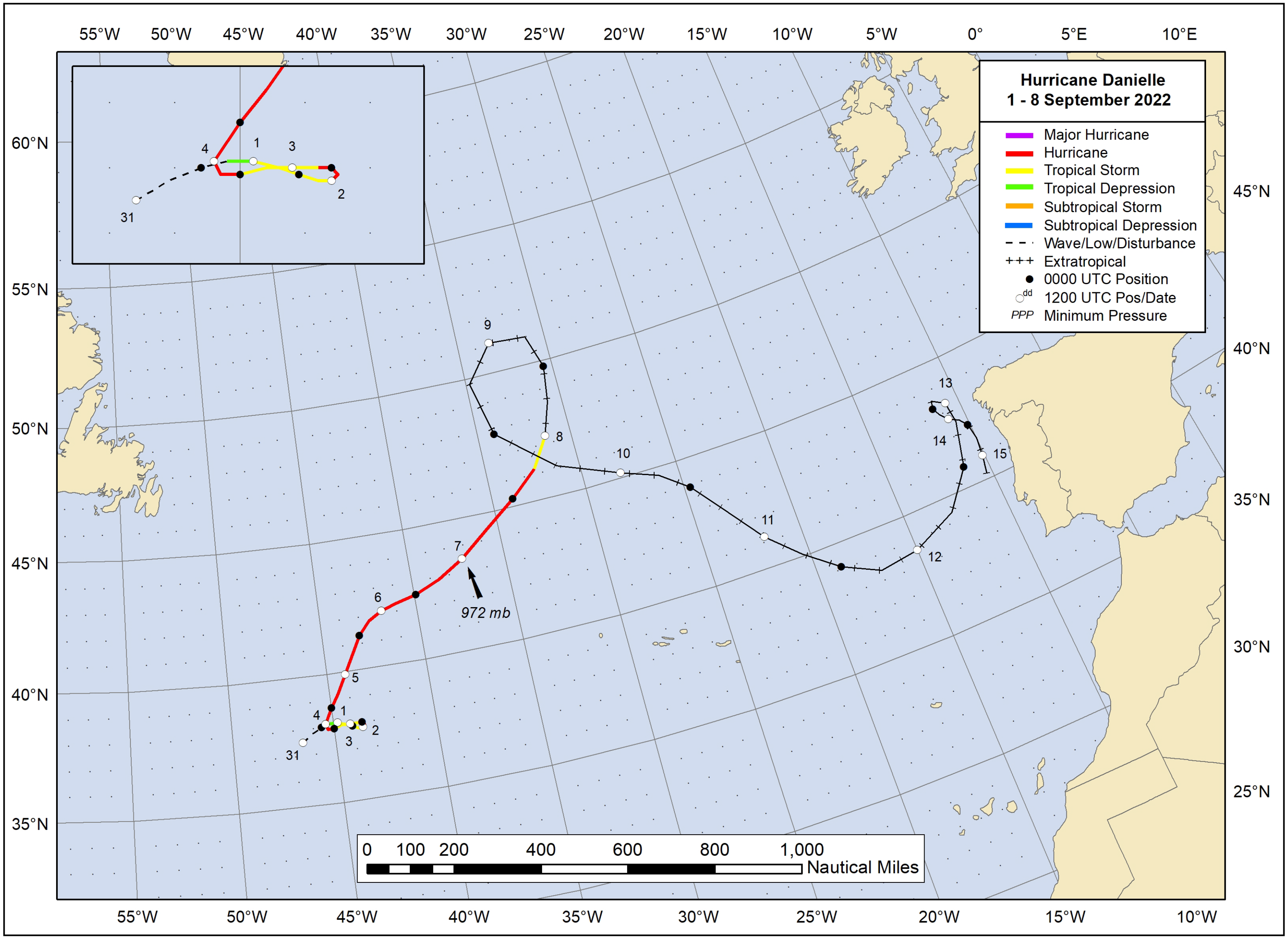

Figure 2. Best track positions for Hurricane Danielle, 1–8 September 2022.

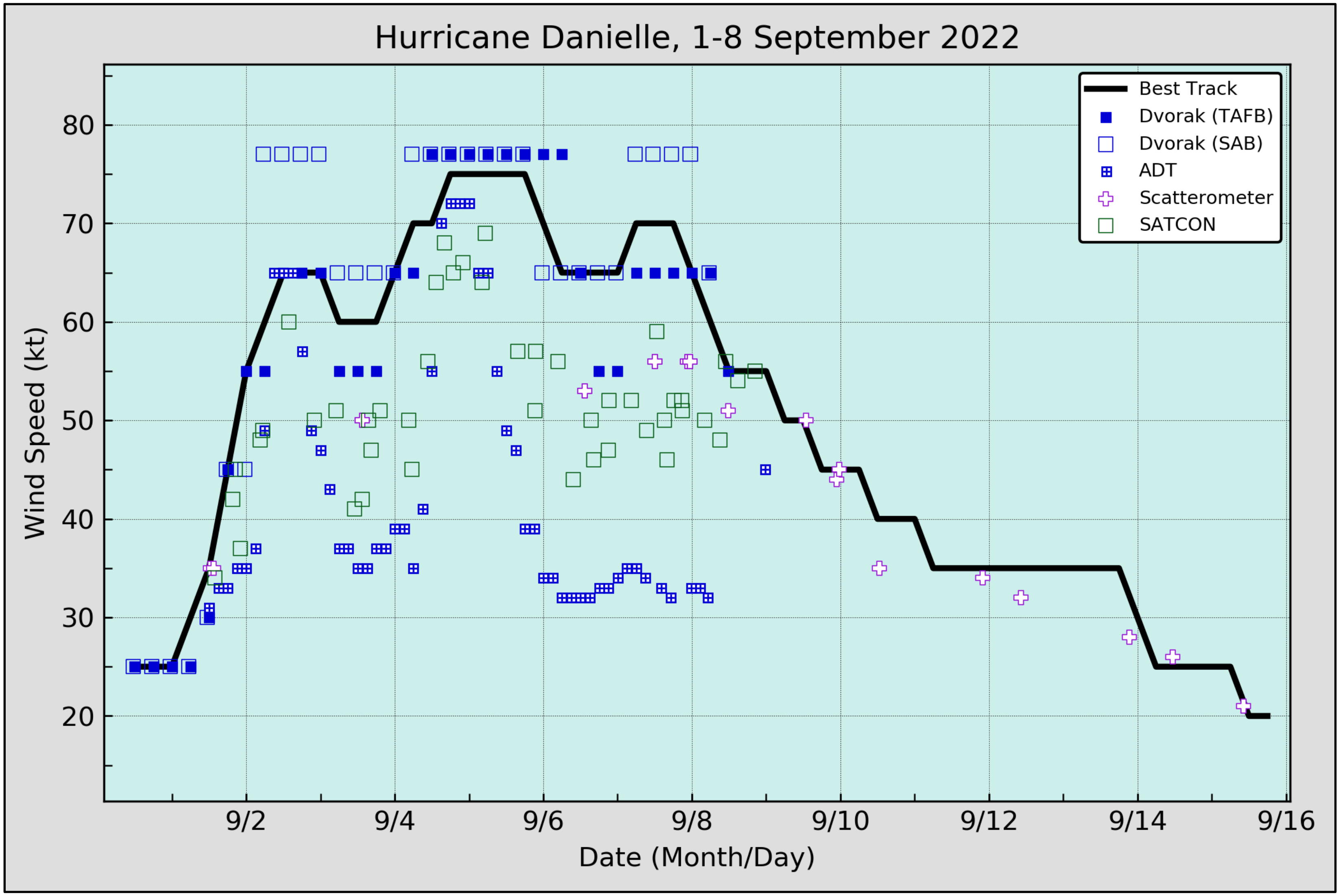

Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Danielle, 1–8 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

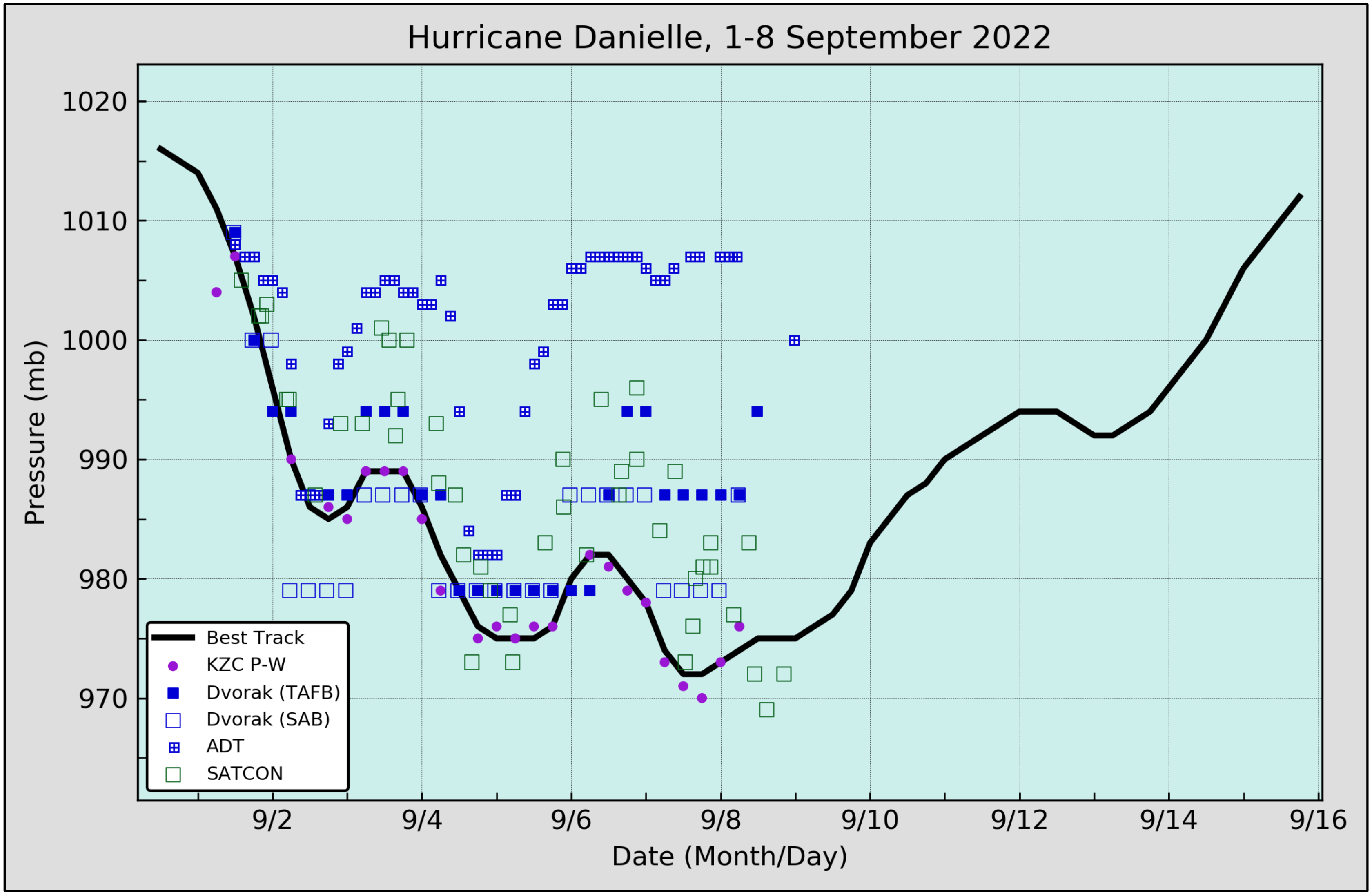

Figure 4. Selected pressure observations and best track minimum central pressure curve for Hurricane Danielle, 1–8 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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.

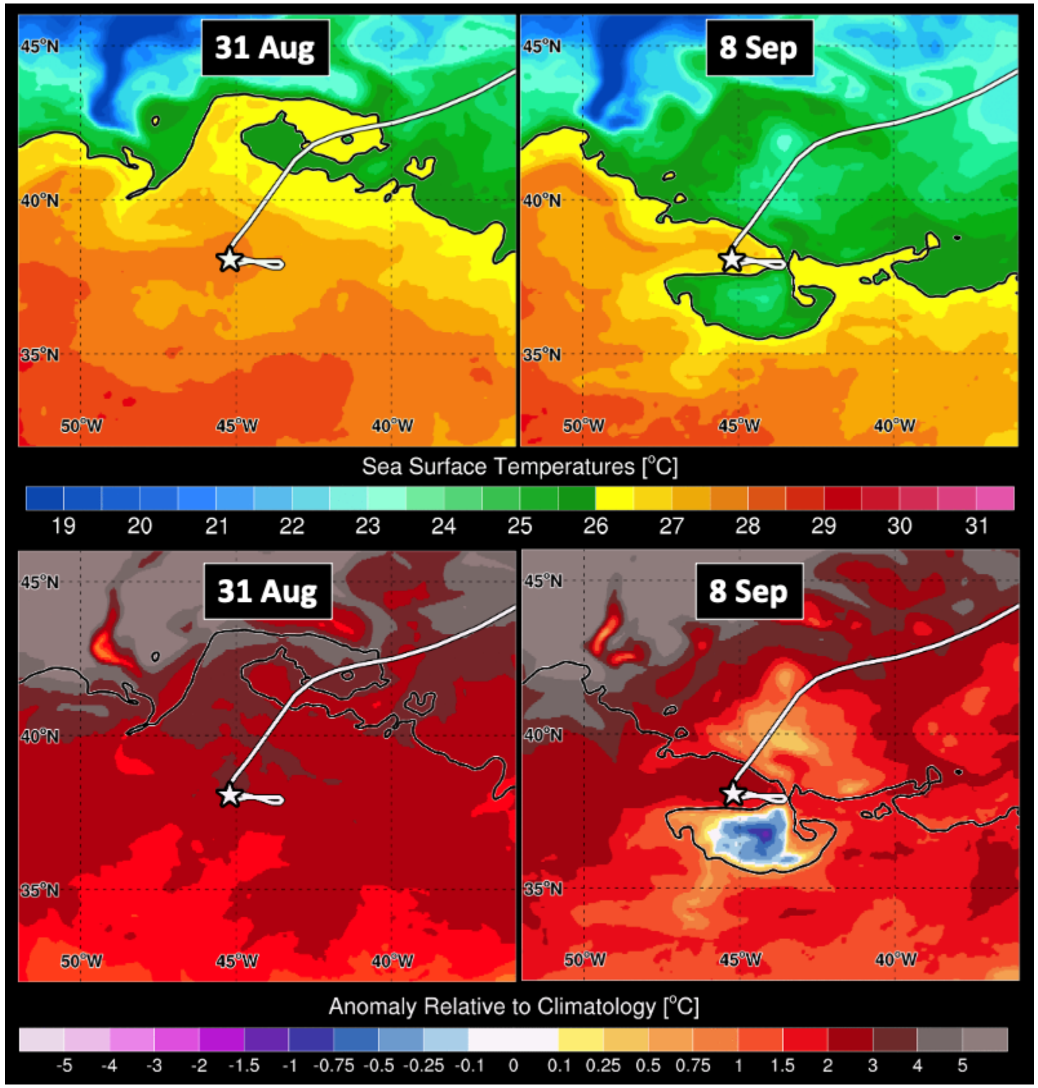

Figure 5. Sea surface temperatures (°C, top panels) and sea surface temperature anomalies relative to a daily climatology (°C, bottom panels) before (31 August, left panels) and after (8 September, right panels) the formation and passage of Hurricane Danielle. The 26°C isotherm is highlighted as a black line, while the track and genesis location of Hurricane Danielle are shown as a white line and star respectively. Data from NOAA's Coral Reef Watch, accessible at https://coralreefwatch.noaa.gov/.

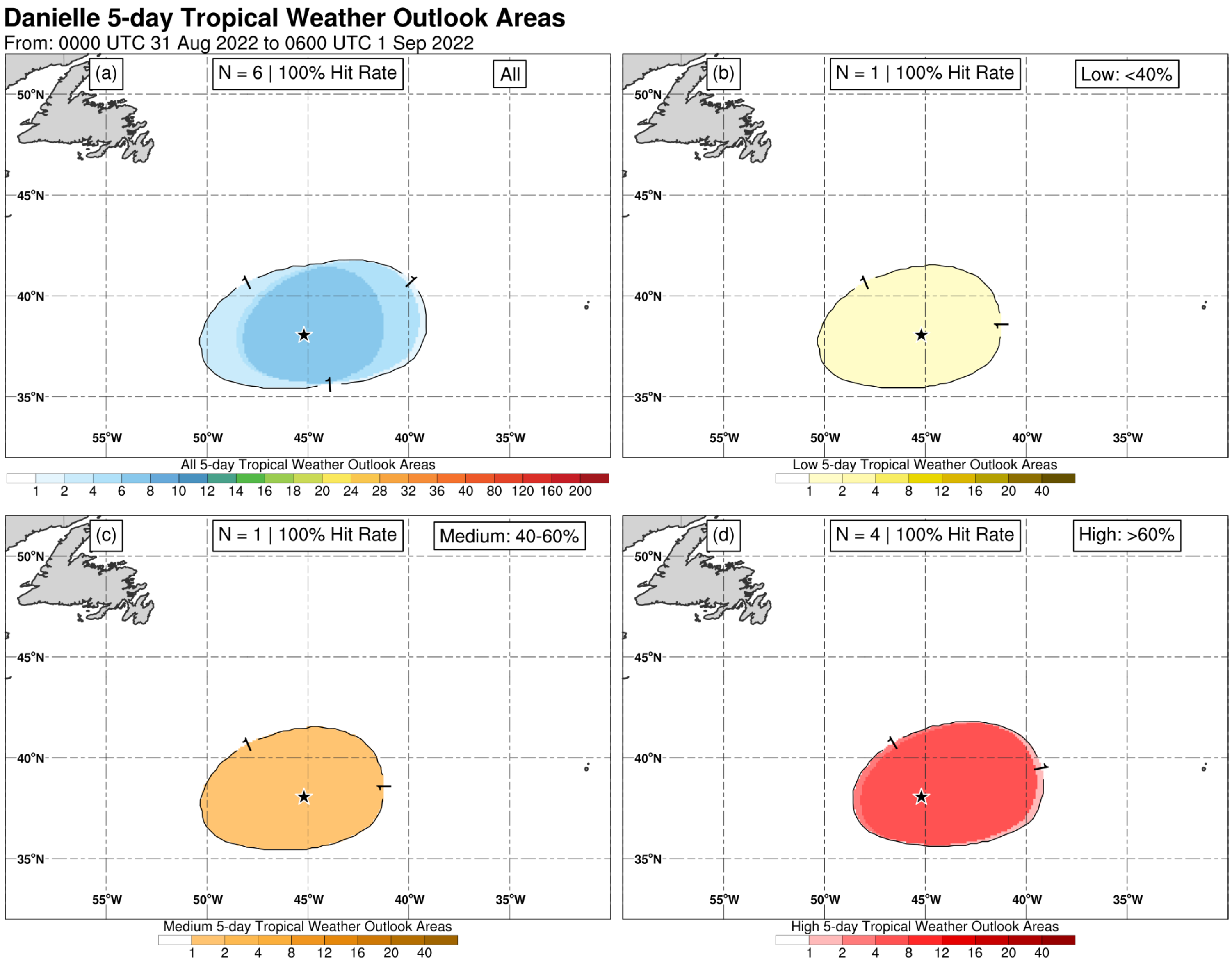

Figure 6. Composites of 5-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Hurricane Danielle for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) medium (40–60%) category, and (d) high (>60%) category. Danielle's location of genesis is indicated by the black star.

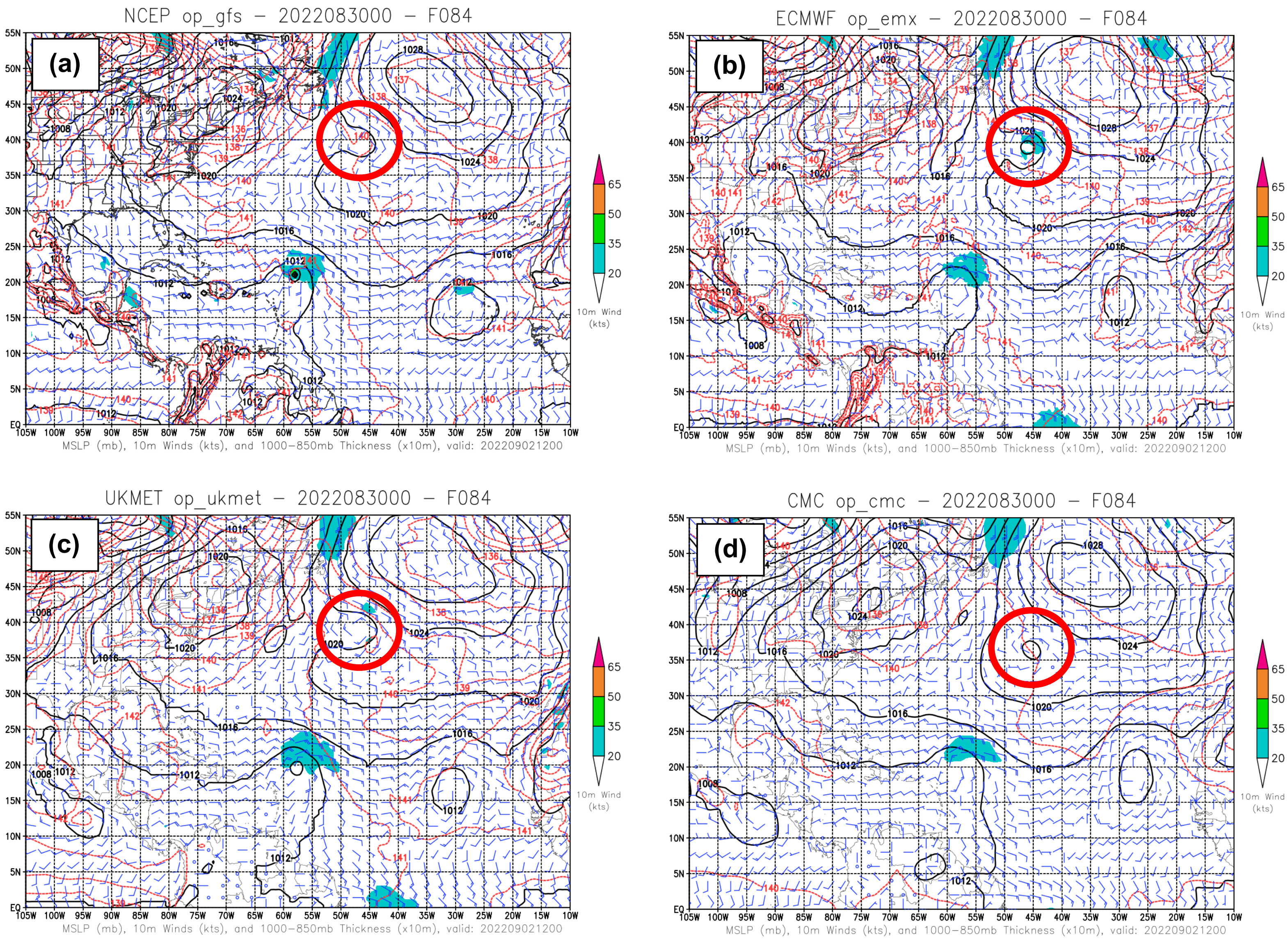

Figure 7. Surface pressure (mb), 10-meter wind (kt), and 1000-850 mb thickness (dam) fields from the (a) GFS, (b) ECMWF, (c) UKMET, and (d) Canadian models initialized at 0000 UTC 30 August 2022 and valid 84 h later at 1200 UTC 2 September when Danielle is estimated to have become a hurricane. The models' depiction of Danielle is indicated by the red circles.

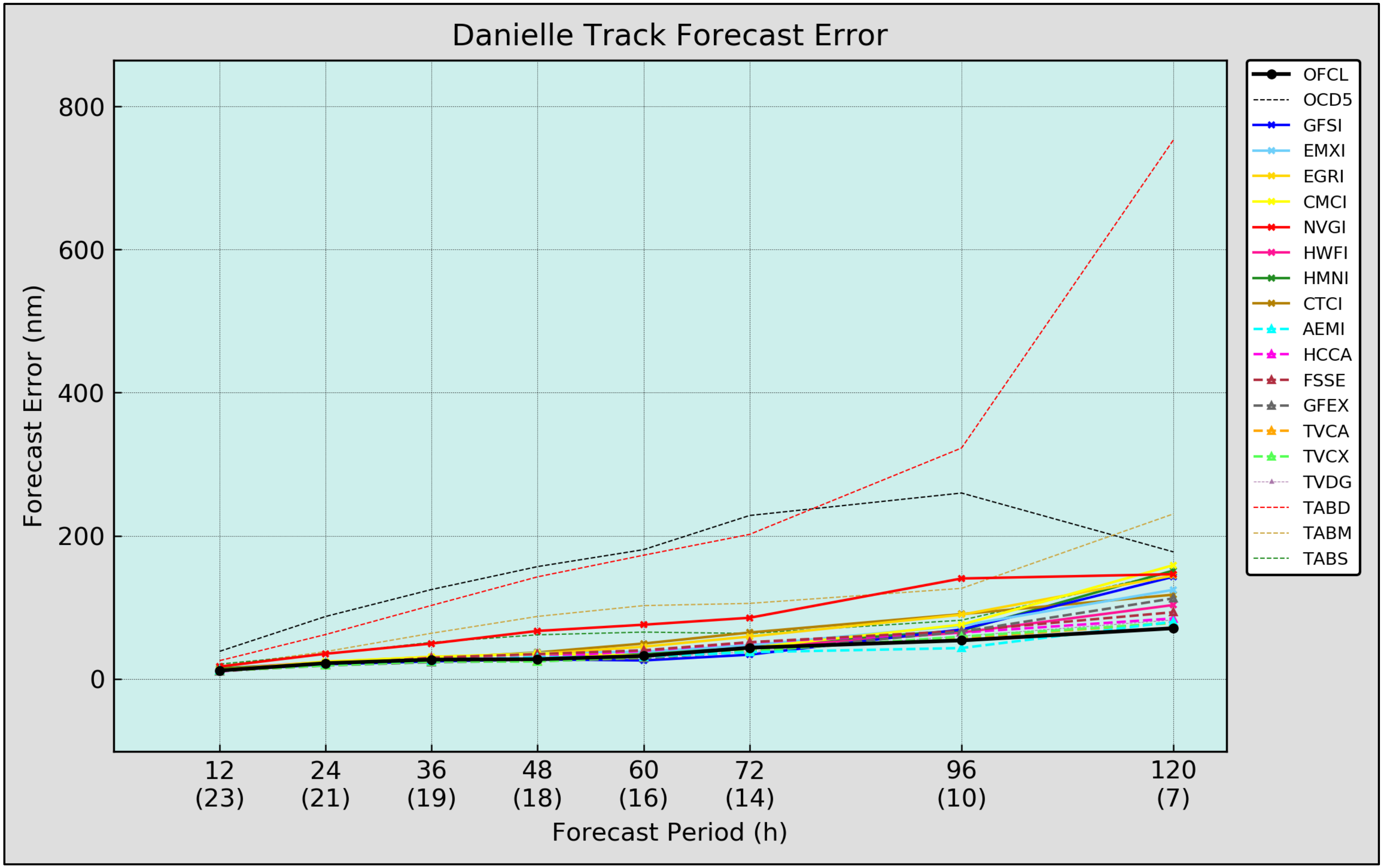

Figure 8. Homogeneous comparison of selected track forecast guidance model errors (in n mi) for Hurricane Danielle, 1–8 September 2022. Official NHC track errors are denoted by the thick black line.

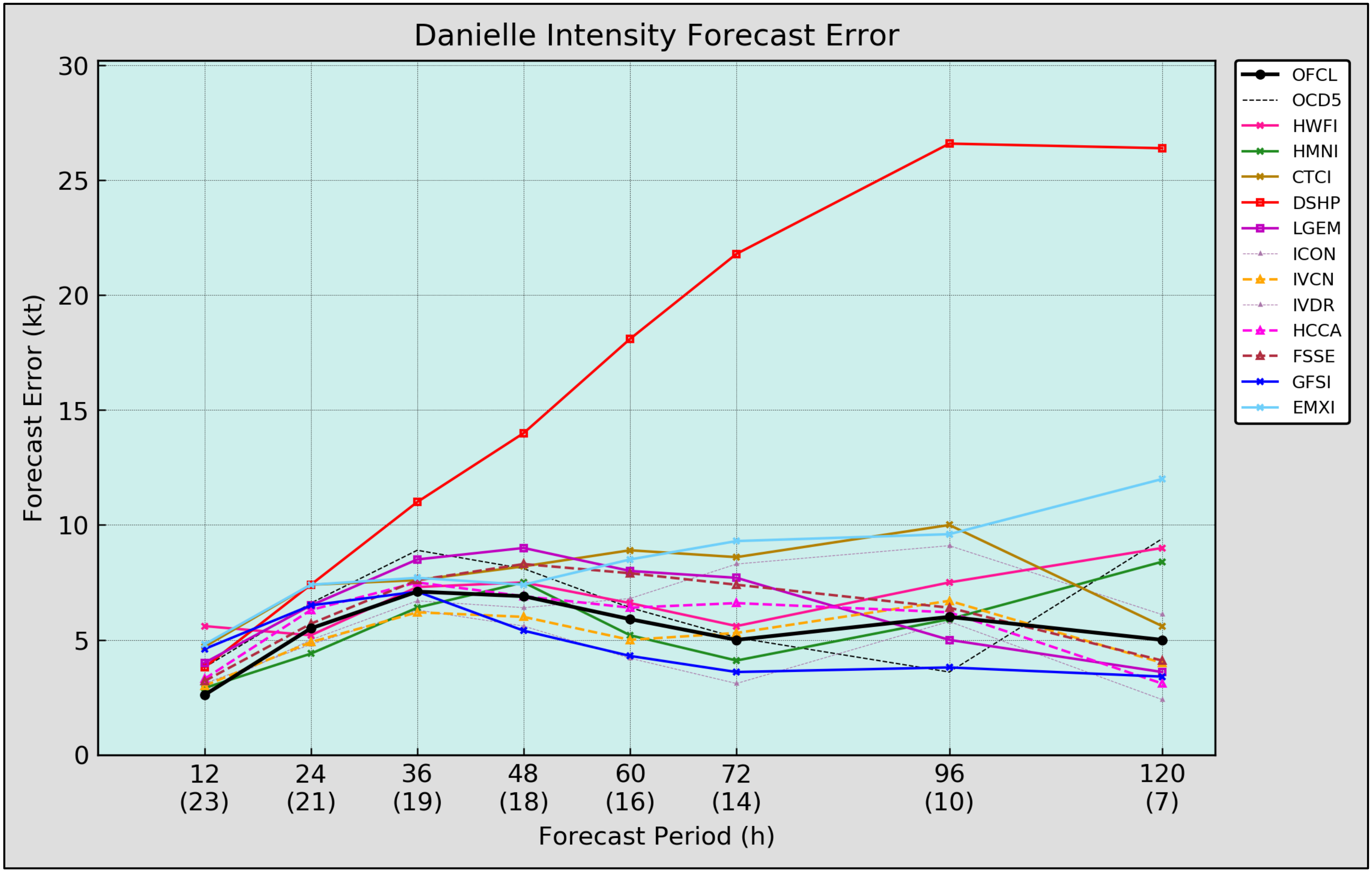

Figure 9. Homogeneous comparison of selected intensity forecast guidance model errors (in kt) for Hurricane Danielle, 1–8 September 2022. Official NHC intensity errors are denoted by the thick black line.