Tropical Cyclone Report
Hurricane Danielle
(AL062010)
21-30 August 2010

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Danielle was a Cape Verde hurricane that reached category 4 strength (on the Saffir-Simpson Hurricane Wind Scale) over the central North Atlantic and recurved to the southeast of Bermuda.

a. Synoptic History

The origin of Danielle was complex. Soundings from Dakar, Senegal, indicate that a strong tropical wave with associated 4-mb pressure falls over 24 h crossed the west coast of Africa on 18 August, introducing a large surge of moisture and a significant increase in instability over the far eastern Atlantic. A day later, a nearly stationary disturbance within an active Intertropical Convergence Zone (ITCZ) was detected a few hundred nautical miles south-southwest of the Cape Verde Islands. As the wave passed the ITCZ disturbance on 20 August, an elongated and large low-level circulation began to develop over the tropical Atlantic east of 30°W, but the associated convection was poorly organized. On the next day the coverage and organization of the convection gradually increased, and a smaller-scale circulation formed along the southwestern end of the larger gyre. Deep convection continued to become better organized, and a banding feature soon developed over the southwest semicircle of the developing circulation. A tropical depression is estimated to have formed around 1800 UTC 21 August about 450 n mi west-southwest of the Cape Verde Islands. 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].

Embedded within strong low-level westerly flow, the depression moved slowly westward and became a tropical storm about 12 h after genesis. The tropical cyclone did not increase further in organization that day, however, in an environment of moderate northeasterly shear. The proximity of Danielle to another disturbance on the eastern end of the broad eastern Atlantic gyre briefly caused the cyclone to turn west-northwestward to northwestward on 22 August. The storm began moving more quickly on a generally westward course on 23 August in response to a building low- to mid-level ridge over the east-central Atlantic. Northeasterly shear decreased around this time as the cyclone escaped the influence of the eastern Atlantic circulation, and Danielle rapidly strengthened into a hurricane while centered around 1800 UTC 23 August about 960 n mi west of the southernmost Cape Verde 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.

After reaching an intensity of 80 kt around 0600 UTC 24 August, southwesterly shear associated with a shortwave trough moving southwestward in the subtropical Atlantic between 45-50°W caused Danielle to decrease in strength. The trough also weakened the subtropical ridge that was steering Danielle, which resulted in a turn toward the west-northwest. Despite a continuation of moderate southwesterly shear, Danielle maintained hurricane strength on 24 August and early on 25 August. Late on 25 August the hurricane turned northwestward and its forward speed decreased in response to a new weakness developing in the subtropical ridge over the central Atlantic. A decrease in shear around that time led to a gradual strengthening of the cyclone on 26 August, and the rate of deepening increased early on 27 August. Danielle is estimated to have reached its peak intensity of 115 kt at 1800 UTC 27 August while located about 440 n mi south-southeast of Bermuda. The cyclone turned north-northwestward and then northward late on 27 August and early on 28 August, slowing further as it reached the western periphery of the subtropical ridge. A gradual weakening trend began during this time in response to a slowly evolving eyewall replacement (Fig. 4).

Danielle continued to slowly weaken in response to increasing southwesterly shear ahead of a deep mid- to upper-level trough moving offshore of the east coast of the United States. This same feature caused the cyclone to turn sharply north-northeastward and accelerate by 29 August, bringing the center of Danielle over progressively cooler waters. Convection decreased substantially on 30 August, and the wind field of the hurricane began to expand as it turned northeastward and decelerated. Turning east-northward and then eastward, Danielle weakened to a tropical storm around 1800 UTC 30 August about 1085 n mi east-northeast of the Azores and became post-tropical 6 h later when its deep convection dissipated. The low accelerated on a generally northeastward course on 31 August over the north-central Atlantic and became extratropical around 1800 UTC 31 August after satellite pictures indicated developing frontal characteristics and AMSU measurements revealed a deterioration of its warm core. On 1 and 2 September the extratropical gale's forward speed decreased while the gale center turned northward over the far North Atlantic. It dissipated several hundred nautical miles east-southeast of the southern tip of Greenland on 3 September.

b. Meteorological Statistics

Observations in Danielle (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), as well as flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), 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.

The Air Force 53rd Weather Reconnaissance Squadron flew two missions into Danielle, obtaining a total of four center fixes. The maximum flight-level wind observed was 119 kt in the

northeastern eyewall at 700 mb at 1552 UTC 27 August 2010. The maximum SFMR wind of 101 kt was measured on the next center pass along with a minimum central pressure of 942 mb. While the flight-level winds from the first pass would normally support an intensity of 105-110 kt, data from the next pass indicated that the pressure was still falling and the eye temperature was warming. In addition, satellite images indicated an increase in organization during the next few hours, and ADT values reached a maximum around 1800 UTC. The maximum intensity of Danielle is estimated to be 115 kt based on a blend of reconnaissance data, satellite intensity classifications of T6.0 from SAB and TAFB at 1745 UTC 27 August, and an ADT estimate of 6.3/122 kt.

A couple of ships and buoys reported tropical-storm-force winds in Danielle, with these reports occurring from 29-31 August when the hurricane was crossing the mid-latitude waters of the central North Atlantic. Of note is a report from Ship *WCZ552* of a peak wind of 64 kt (averaging period unknown) and a minimum pressure of 974.1 mb at 1300 UTC 30 August while located about 20 n mi east-southeast from the center of Danielle. A summary of ship and buoy reports from Danielle is given in Table 2.

c. Casualty and Damage Statistics

One death was associated with Danielle. A 47-year old man drowned in rough surf conditions generated by long period swells arriving at Seagull Park in Satellite Beach, Florida. Lifeguards also rescued 68 people in Brevard and several dozen in Volusia counties from rough surf or rip currents.

d. Forecast and Warning Critique

Danielle's genesis was fairly well forecast. The disturbance from which Danielle developed was first introduced into the Tropical Weather Outlook 48 h prior to genesis and reached the medium category (30 to 50%) 18 h later. Genesis probabilities, however, never reached the high category (greater than or equal to 60%) despite the strong signal in the global models a couple of days prior to the formation of this system. The lack of even greater confidence in the genesis of Danielle likely stemmed from the complexity of its initial development as well as the uncertain timing of the event.

A verification of NHC official track forecasts for Danielle is given in Table 3a. Official forecast track errors were greater than the mean official errors for the previous 5-yr period at all forecast time intervals except at 48 h and 72 h. OCD5 errors were greater than those for an average cyclone over the previous 5 yr, suggesting that Danielle's track was difficult to forecast. The larger-than-normal errors before 48 h were generally related to forecasts that were too far northward early in the lifecycle of Danielle. A comparison of operational and best track positions indicates that these errors were a consequence of the difficulty in determining the storm's initial location. The higher than normal errors at 96 h and 120 h are associated with the inability of forecasts to correctly predict the sharpness of Danielle's recurvature. A homogeneous comparison of the official track errors with selected guidance models is given in

Table 3b. A number of models outperformed the official forecast, most notably the AEMI and FSSE at all forecast times except 120 h. EMXI was superior to all models from 72 to 120 h.

A verification of NHC official intensity forecasts for Danielle is given in Table 4a. Official forecast intensity errors were larger than the mean official errors for the previous 5-yr period through 36 h but lower than the mean official errors after that time. OCD5 errors compared against the previous 5-yr mean indicate near or below average difficulty in forecasting Danielle's intensity except at 120 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The FSSE and IVCN consensus models were the best-performing guidance for Danielle, generally beating the official forecast at all forecast time intervals after 12 h. Several other models also performed better than the official forecast. GHMI and ICON did so at and after 36 h while the LGEM beat the official forecast at and after 72 h. The greater-than-normal intensity errors were primarily associated with early forecasts that did not anticipate the weakening phase that Danielle underwent on 24 August and forecasts around the time of peak intensity that predicted that Danielle would maintain its intensity longer than it did.

A Tropical Storm Watch was issued by the Bermuda Weather Service at 2100 UTC 27 August but was discontinued 24 h later after Danielle began to recurve well to the east of that island (Table 5).

Table 1. Best track for Hurricane Danielle, 21-30 August 2010.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
21 / 1200	10.7	31.1	1009	25	low
21 / 1800	11.0	31.7	1008	25	tropical depression
22 / 0000	11.4	32.4	1007	30	"
22 / 0600	11.8	33.1	1005	35	tropical storm
22 / 1200	12.4	33.9	1005	35	"
22 / 1800	13.2	34.8	1004	35	"
23 / 0000	13.8	35.9	1000	45	"
23 / 0600	14.2	37.4	997	50	"
23 / 1200	14.7	39.1	994	55	"
23 / 1800	15.2	40.9	987	65	hurricane
24 / 0000	15.4	42.6	982	75	"
24 / 0600	15.6	44.2	977	80	"
24 / 1200	16.2	45.8	984	70	"
24 / 1800	17.0	47.5	987	65	"
25 / 0000	17.7	49.0	984	70	"
25 / 0600	18.4	50.4	984	70	"
25 / 1200	19.4	51.6	984	70	"
25 / 1800	20.7	52.6	980	75	"
26 / 0000	22.0	53.6	977	80	"
26 / 0600	23.1	54.6	973	85	"
26 / 1200	24.0	55.4	973	85	"
26 / 1800	24.8	56.4	970	90	"
27 / 0000	25.6	57.3	966	95	"
27 / 0600	26.2	58.3	953	110	"
27 / 1200	26.5	59.3	948	110	"
27 / 1800	27.1	60.1	942	115	"
28 / 0000	27.7	60.5	946	105	"
28 / 0600	28.3	61.0	950	95	"
28 / 1200	28.9	60.8	952	95	"
28 / 1800	29.6	60.2	955	90	"
29 / 0000	30.9	59.2	958	85	"

29 / 0600	32.4	57.9	964	80	"
29 / 1200	34.7	56.2	966	75	"
29 / 1800	37.3	55.0	968	75	"
30 / 0000	38.7	53.8	969	70	"
30 / 0600	40.0	52.8	970	65	"
30 / 1200	40.6	51.6	970	65	"
30 / 1800	41.0	50.2	973	60	tropical storm
31 / 0000	41.1	48.0	976	60	low
31 / 0600	41.2	44.8	981	55	"
31 / 1200	41.3	41.0	985	55	"
31 / 1800	42.1	35.9	987	50	extratropical
01 / 0000	43.5	30.4	988	45	"
01 / 0600	44.8	26.3	990	40	"
01 / 1200	46.2	24.0	991	40	"
01 / 1800	47.9	22.0	992	40	"
02 / 0000	49.5	20.7	994	40	"
02 / 0600	51.1	19.9	995	40	"
02 / 1200	53.0	20.3	996	35	"
02 / 1800	55.0	21.5	998	35	"
03 / 0000	57.5	23.0	998	30	"
03 / 0600					dissipated
27 / 1800	27.1	60.1	942	115	Maximum wind and minimum pressure

Table 2. Selected ship and buoy reports with winds of at least 34 kt for Hurricane Danielle, 21-30 August, 2010.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
23 / 0800	13008	15.0	38.0	040 / 41	998.1
29 / 1200	C6TQ6	32.4	64.7	350 / 37	1016.0
29 / 1600	44755	38.0	57.5	040 / 45	1000.8
29 / 1900	44755	38.0	57.6	010 / 39	997.4
30 / 0600	WGAX	41.0	59.5	340 / 38	1011.0
30 / 0900	WGAX	41.0	58.6	350 / 44	1011.0
30 / 1300	WCZ552	40.4	51.1	170 / 64	974.1
31 / 0400	WCZ552	40.3	47.7	290 / 52	993.7
31 / 0600	WCZ552	40.4	47.1	290 / 44	996.9

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Danielle, 21-30 August 2010. Mean errors for the five-year period 2005-9 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	39.0	65.5	78.8	**90.8**	**140.9**	231.9	297.3
OCD5	63.4	135.9	192.7	250.1	282.5	269.7	405.2
Forecasts	36	34	32	30	26	22	18
OFCL (2005-9)	31.8	53.4	75.4	96.8	143.8	195.6	252.1
OCD5 (2005-9)	46.9	97.3	155.4	211.6	304.8	387.9	467.8

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Danielle, 21-30 August 2010. 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	34.6	58.9	73.6	85.0	143.4	238.7	357.9
GFSI	34.7	61.0	74.0	85.5	145.3	249.8	421.0
GFDI	41.6	62.8	75.2	**84.9**	**140.8**	**223.1**	406.2
HWFI	40.8	63.8	83.6	100.3	**129.8**	**201.4**	397.4
GFNI	40.1	73.1	97.1	114.7	170.0	291.0	498.2
NGPI	37.0	72.2	96.2	112.0	190.4	340.2	519.0
EGRI	36.3	60.0	78.4	87.3	**112.0**	**176.5**	**315.6**
EMXI	37.6	60.1	77.2	**82.5**	**112.2**	**150.5**	**211.1**
AEMI	**33.4**	**54.1**	**71.7**	**79.9**	**126.3**	**197.6**	377.6
FSSE	**32.1**	**52.5**	**63.5**	**72.9**	**117.6**	**200.2**	363.1
TCON	35.0	**58.6**	73.8	**84.9**	**130.9**	**222.8**	395.5
TCCN	37.2	63.3	78.8	90.4	147.9	262.8	457.4
TVCN	34.7	**58.6**	75.4	85.7	**127.7**	**215.2**	376.4
TVCC	36.8	62.7	79.3	90.7	146.4	252.1	424.7
GUNA	34.6	**58.5**	74.0	**82.4**	**132.0**	**230.3**	397.7
CGUN	36.5	63.4	79.4	89.4	150.8	267.9	464.4
LBAR	43.6	79.1	110.0	127.7	**134.2**	239.7	378.7
BAMS	58.9	95.9	123.1	148.4	221.4	310.8	510.1
BAMM	47.0	85.7	112.4	129.7	166.3	280.1	467.3
BAMD	48.7	100.5	141.3	164.7	177.1	343.1	520.3
Forecasts	21	19	18	17	15	13	10

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Danielle, 21-30 August 2010. Mean errors for the five-year period 2005-9 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	7.4	12.5	14.4	**13.3**	**12.1**	**13.9**	**15.8**
OCD5	8.4	12.6	15.7	16.7	15.8	17.8	26.2
Forecasts	36	34	32	30	26	22	18
OFCL (2005-9)	7.0	10.7	13.1	15.2	18.6	18.7	20.1
OCD5 (2005-9)	8.6	12.5	15.8	18.2	21.0	22.7	21.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Danielle, 21-30 August 2010. 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	8.0	12.7	13.9	13.8	13.1	15.0	15.8
OCD5	9.0	12.7	**13.6**	14.3	13.8	**13.8**	16.9
HWFI	9.3	13.9	14.5	15.6	22.3	17.7	**12.6**
GHMI	9.1	14.3	**13.0**	**10.4**	**12.2**	17.8	**12.4**
DSHP	9.1	14.1	15.7	16.2	14.3	**13.1**	**13.6**
LGEM	8.6	12.7	14.0	14.8	**12.4**	**12.2**	**11.6**
ICON	8.4	13.1	**12.9**	**12.5**	13.5	**14.5**	**12.8**
FSSE	8.3	**12.3**	**11.9**	**12.1**	**13.0**	17.3	**12.9**
IVCN	8.4	**12.0**	**11.4**	**10.8**	**12.9**	**14.8**	**15.0**
Forecasts	28	28	27	25	21	17	13

Table 5. Watch and warning summary for Hurricane Danielle, 21-30 August 2010.

Date/Time (UTC)	Action	Location
27 / 2100	Tropical Storm Watch issued	Bermuda
28 / 2100	Tropical Storm Watch discontinued	Bermuda

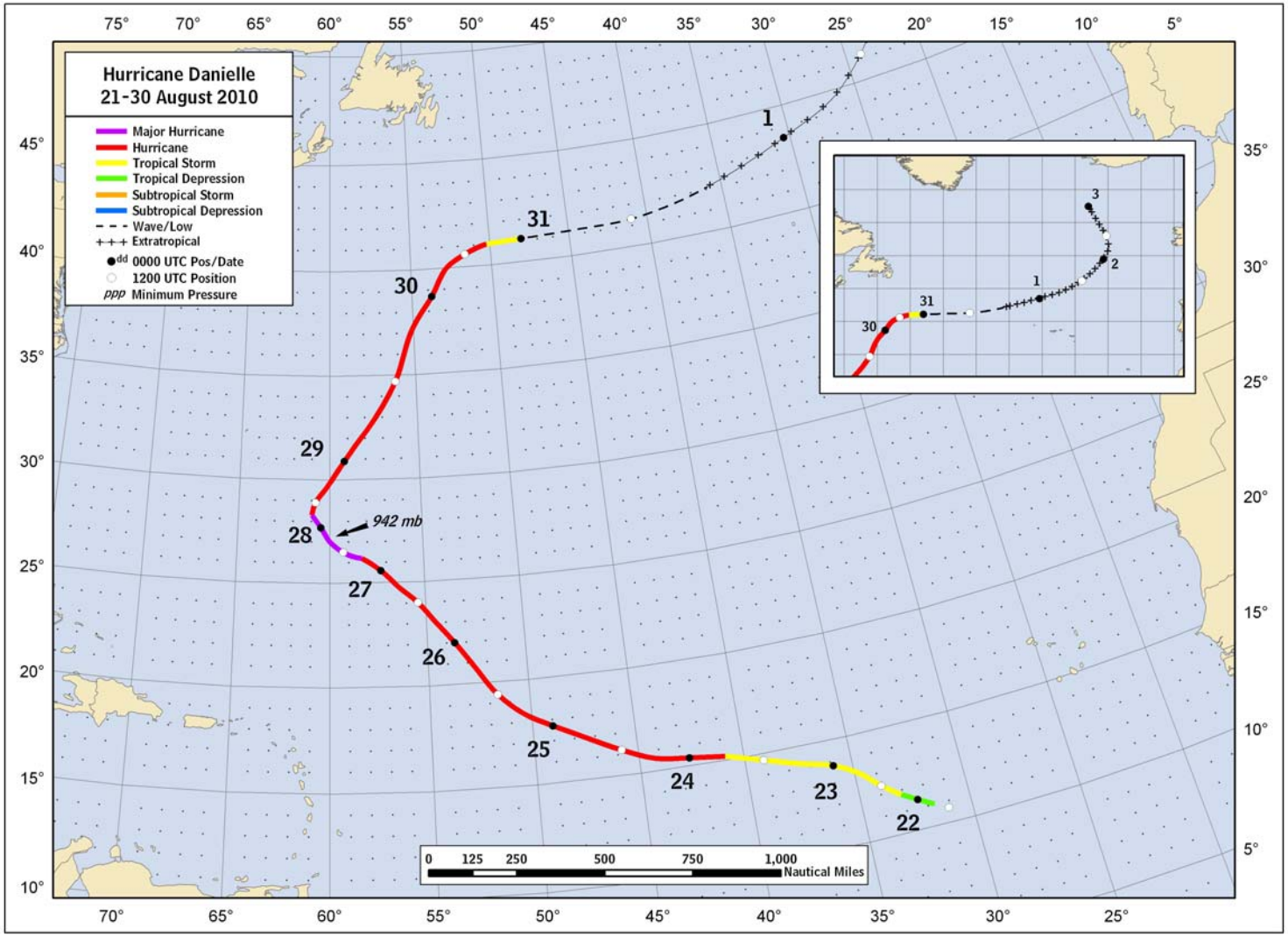

Figure 1. Best track positions for Hurricane Danielle, 21-30 August, 2010. Track during the extratropical stage is based on analyses from the NOAA Ocean Prediction Center.

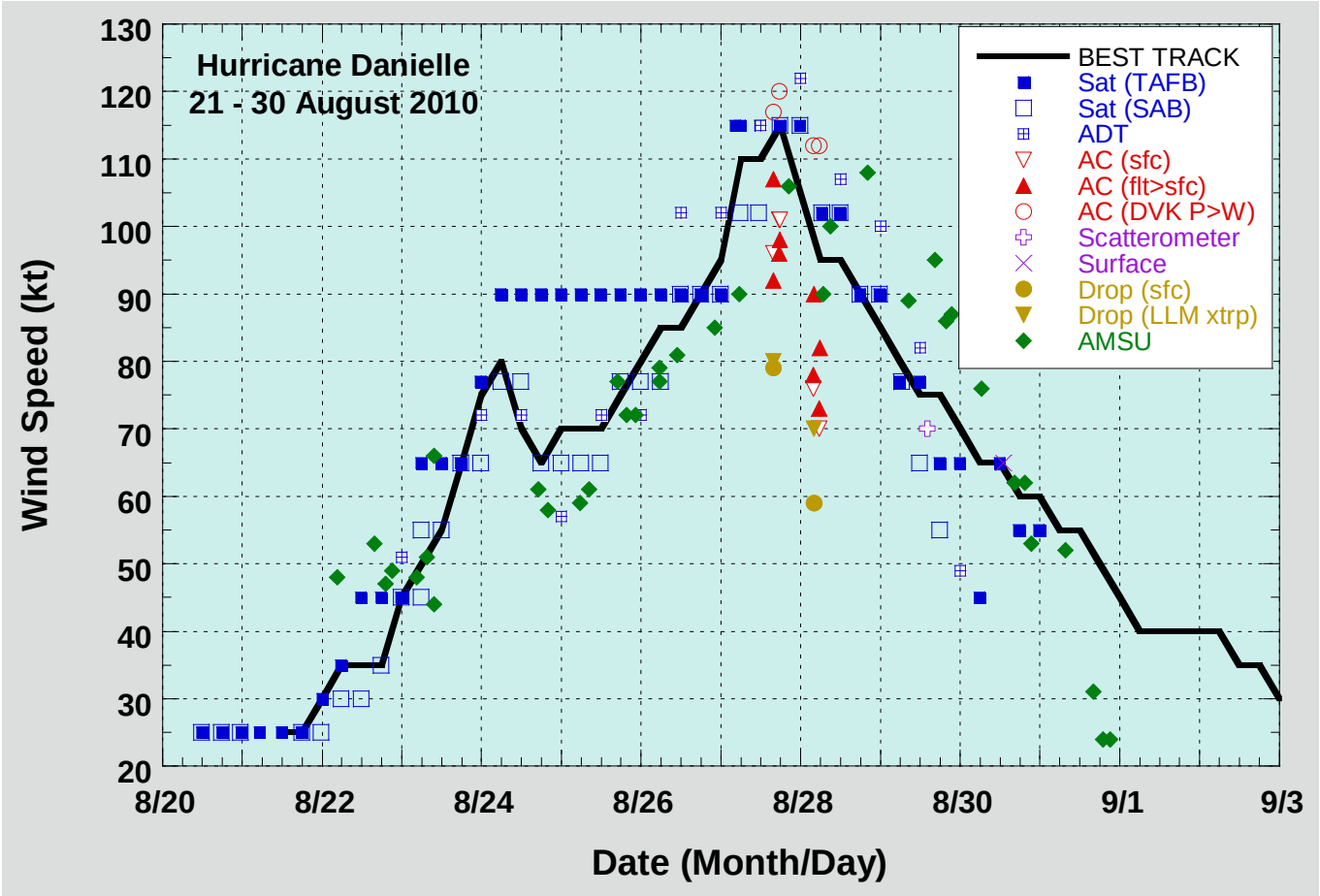

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Danielle, 21-30 August 2010. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC.

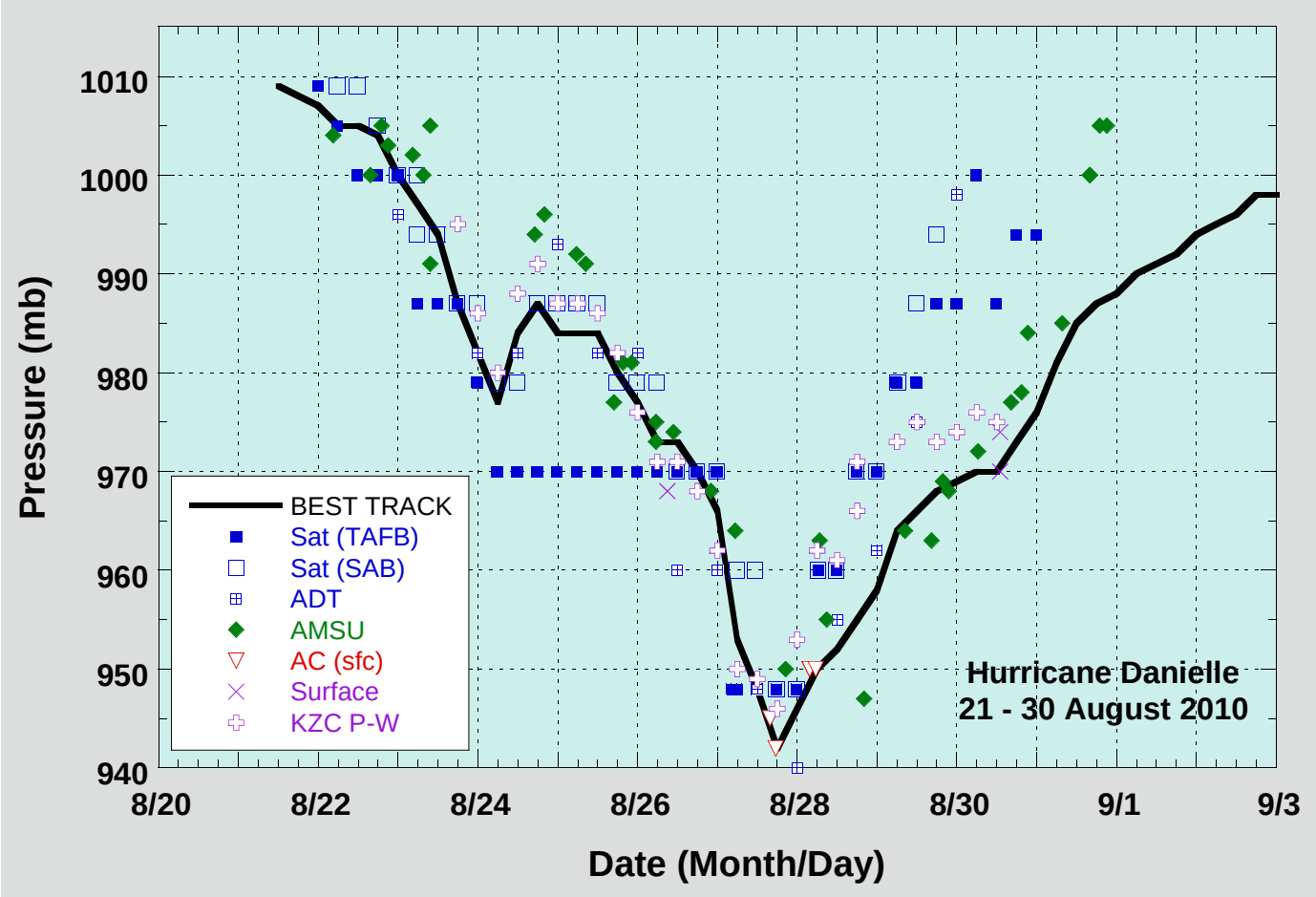

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Danielle, 21-30 August 2010. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. Estimates during the extratropical stage are based on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship.

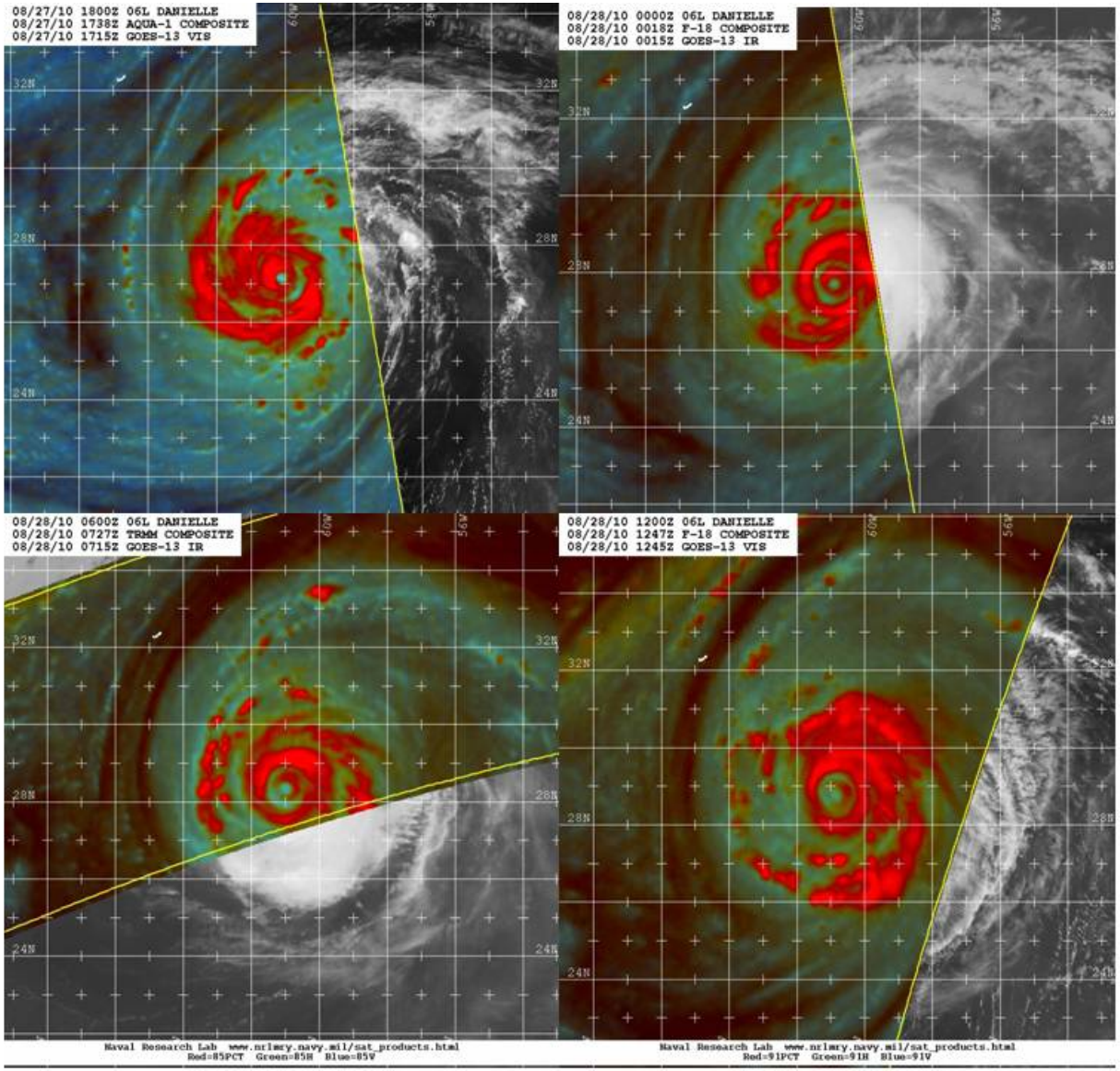

Figure 4. Series of microwave satellite images showing an eyewall replacement of Danielle on 27 and 28 August 2010. Images courtesy of the Naval Research Laboratory.