

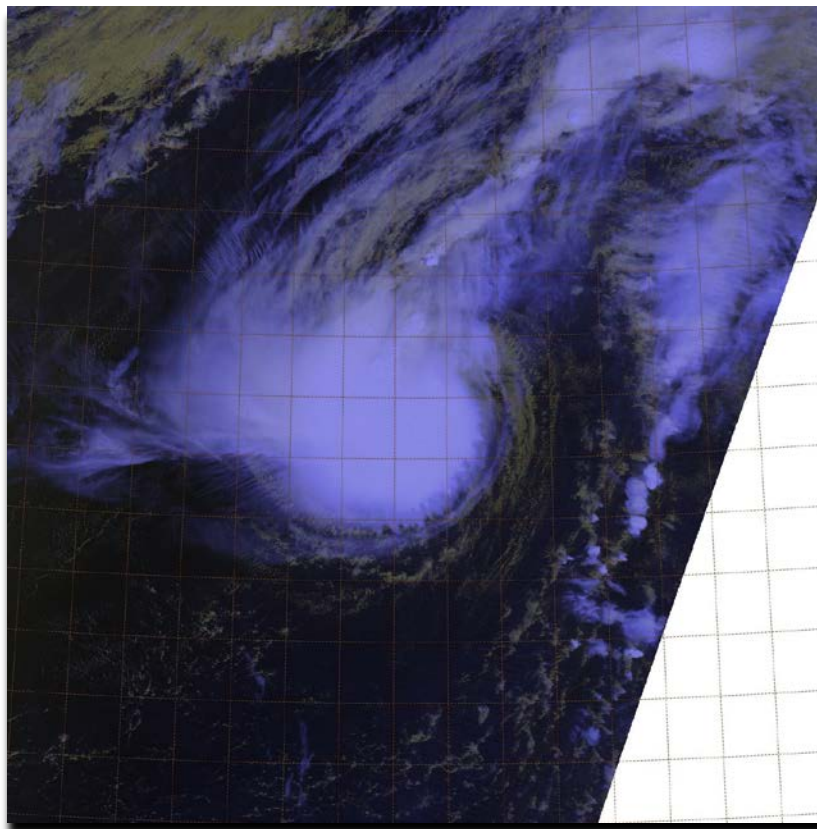


NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE FAY (AL072014)

10 – 13 October 2014

Todd B. Kimberlain
National Hurricane Center
17 December 2014



NPP VIIRS NIGHTTIME VISIBLE IMAGE OF HURRICANE FAY AT 0653 UTC 12 OCTOBER

Fay was a short-lived hurricane of non-tropical origin that passed over Bermuda before turning east-northeastward into the north-central Atlantic Ocean. Fay became the first hurricane to make landfall on Bermuda since Emily of 1987.

Hurricane Fay

10 – 13 OCTOBER 2014

SYNOPTIC HISTORY

A lobe of vorticity broke off of a mid- to upper-level trough over the east-central Atlantic Ocean and moved westward on 7 October. A large area of showers and thunderstorms formed in association with this system that day several hundred miles northeast of the northern Lesser Antilles, with the developing convection possibly enhanced by a surge of moisture from an easterly wave passing to the south. The area of vorticity transformed into a cold low on 8 October while moving westward and induced the development of a sharp surface trough, but southwesterly shear delayed any further organization of the low-level disturbance during the next day or so. When the cold low became nearly situated over the disturbance on 9 October, the shear relaxed, and a comma-shaped band developed, and the curvature and length of this feature increased later that day. An ASCAT pass at 0057 UTC 10 October indicated a large area of 25 to 30 kt winds, with the strongest winds about 120 to 140 n mi from the center of a well-defined surface low pressure system. The convective organization of the low continued to increase, and the system became a subtropical storm about 535 n mi south of Bermuda at 0600 UTC 10 October. The “best track” chart of the Fay’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 1¹.

The subtropical storm moved north-northwestward around the western periphery of a mid-level ridge over the central Atlantic, while maintaining a large and asymmetric mass of convection on the northwestern side of a partially exposed low-level circulation center. The shear increased when the cyclone moved away from the protective cover provided by the nearby cold low, and the convection persisted and contributed to middle- and upper-tropospheric warming by 11 October. The first reconnaissance mission into the storm late on 10 October found that the radius of maximum winds had decreased to about 40 n mi, which was consistent with a concentration of convection closer to the center and increased banding, and Fay became a tropical cyclone by 0600 UTC 11 October. While the evolution to a tropical cyclone was taking place, strong upper-level divergence associated with the cold low to the west of the cyclone may have contributed to Fay’s intensifying from a 40- to a 55-kt tropical storm, even though the vertical shear remained high.

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 *bt* directory, while previous years’ data are located in the *archive* directory.

Fay turned northward and then north-northeastward while accelerating as it moved north of the mid-level ridge axis. Additional strengthening occurred in spite of even stronger south-southwesterly 850-200 mb shear of nearly 35 kt, and Fay reached hurricane strength while it approached Bermuda around 0600 UTC 12 October. Aircraft and satellite data showed that Fay continued to possess an asymmetric cloud pattern and wind distribution, with the deepest convection and strongest winds located in a large band over the western and southwestern part of the circulation when Fay passed over the island around 0800 UTC that day (Fig. 4). Strong winds and heavy rains in that band buffeted Bermuda a couple of hours after Fay made landfall.

Fay then turned sharply toward the east-northeast and accelerated in response to a shortwave trough moving through Atlantic Canada. Strong southwesterly vertical wind shear associated with this upper-level trough began to affect Fay, and satellite data showed that the separation between the low- and mid-level centers was rapidly increasing. Fay weakened to a tropical storm by 1800 UTC 12 October, with the surface circulation quickly becoming elongated while the cyclone's forward speed increased to greater than 20 kt. Additional weakening occurred (Fig. 5 shows the evolution of Fay's cloud pattern during this time), and Fay degenerated into an open trough by 0600 UTC 13 October before regenerating as a frontal cyclone over the northeastern Atlantic later that day. The frontal cyclone sped eastward and then east-southeastward well southwest of the Azores by late on 14 October and lost its identity along the front over the northeastern Atlantic on 15 October.

METEOROLOGICAL STATISTICS

Observations in Fay (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. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from four flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), 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 Fay.

Ship reports of winds of tropical storm force associated with Fay are given in Table 2. The Norwegian Dawn cruise liner (call sign **C6FT7**), located just north of Bermuda at 1000 UTC 12 October, reported 55-kt sustained winds and a pressure of 994.6 mb. A few other ships near or east of Bermuda also reported tropical-storm-force winds. Buoy 41049, located a few hundred miles south of Bermuda, reported a minimum pressure of 1004.1 mb and maximum 1-min winds of 34 kt on 11 October.

Selected surface observations from land stations and data buoys are given in Table 3. Operationally, Fay was assessed to be a tropical storm as it passed Bermuda. However, data obtained subsequently indicate that it was a hurricane. The estimated peak intensity of 70 kt is

based primarily on radar data and surface data from Bermuda. A maximum 10-min wind of 53 kt was measured at the official site at the Bermuda Airport (TXKF), with winds 20-40% higher reported elsewhere on the island at elevations well above the standard 10-m elevation. The application of a gust factor to the TXKF wind observation yields a peak 1-minute wind of 59 kt (Harper et al. 2009). A Weather Underground site at Smith's Parish reported a 70-kt 1-min wind at a height of 40 m, which corresponds to about 62 kt at 10 m. A 76-kt 10-min sustained wind was measured atop Commissioner's Point at an elevation of about 46 m above ground level, yielding a peak 1-min wind of 74 kt at 10 m (although the siting of the Commissioner's Point observations makes its representativeness uncertain). Wind gusts over hurricane force were commonplace throughout the island, with over 100-kt gusts reported at elevated locations. Radar velocity data (Fig. 6), which include winds of 85 kt at an altitude of roughly 1000 ft, support peak winds of at least 65 kt. In addition, there was a UW-CIMSS objective Dvorak classification of T4.4/75 kt at 0600 and 1200 UTC 12 October and a few AMSU passes around 1000 UTC between 63 and 75 kt.

The lowest observed pressure on Bermuda (984.5 mb) was measured in Smith's Parish near Flatt's Village at 0810 UTC. Another notable minimum pressure of 985.1 mb was measured at TXKF at 0820 UTC, when the station was reporting very light northerly winds. A rainfall total of 1.87 inches (47.5 mm) was measured at TXKF, but the funnel to the rain gauge was apparently carried away by the wind before the height of the storm. An unofficial total of 3.70 inches (94 mm) of rain was recorded by a member of the public on the west end of the island, but the gauge was tipped over at an angle by the gusty winds. A storm tide of 1.78 ft (0.54 m) was measured by a NOAA tide gauge at St. George on the north coast of the island. Higher values could have occurred on the southern and western sides of the island, coincident with the strongest winds.

Radar and surface data indicate that the center of Fay passed over Bermuda a little after 0800 UTC. Velocity data from the Bermuda radar show the zero isodop directly over the island around this time. Near-calm conditions were experienced at the Bermuda Causeway (Fig. 5) a few minutes after 0800 UTC and at the Bermuda Airport around 0820 UTC, nearly coincident with the time of pressure minima between 984 and 985 mb at the airport and in Smith's Parish. Based on these data, Fay's center is estimated to have made landfall around 0810 UTC, making Fay the first hurricane to make landfall on Bermuda since Emily of 1987. The western half of the island was located within Fay's radius of maximum winds, with hurricane-force winds at Commissioner's Point on the far southwestern side of the island and near hurricane-force winds in Smith's Parish. The eastern and northern end of the island experienced somewhat lower winds, as evidenced by the 59-kt peak 1-minute wind at the Bermuda Airport.

CASUALTY AND DAMAGE STATISTICS

Fay's winds toppled utility poles, downed trees and street signs throughout Bermuda, with the damage likely exacerbated by saturated soils after nearly 14 inches of rain on the island in August and above normal rains in September. Nearly 27,000 customers were left without power. Isolated roof and vehicle damage was reported, though most of the damage was minor. Strong winds damaged the roof of the terminal building at the L.F. Wade International Airport, with several reports of severe flooding in that building. Several major roads were inundated, including Front

Street in Hamilton. Large boats broke from their moorings and were pushed onshore, heavily damaged or destroyed.

One insurer on Bermuda preliminarily estimated their losses from Fay to be near \$3.8 million. With several other insurers on the island, the total monetary losses are likely significantly higher, but there are no additional estimates at this time. Since Gonzalo affected Bermuda within six days of Fay's passage, it may be difficult to separate the impacts from the two storms.

FORECAST AND WARNING CRITIQUE

The genesis of Fay was poorly forecast (Table 4). The system from which Fay developed was introduced in the short- and extended-range portions of the Tropical Weather Outlook (TWO) only 36 h prior to genesis. The likelihood of genesis reached the medium category in the extended- and short-range forecasts 30 h and 18 h before genesis occurred, respectively. The chance of subtropical or tropical cyclogenesis was then increased to the high category (60% or greater) only 6 h prior to genesis.

Providing adequate genesis lead times for cyclones that have non-tropical origins has proven to be a challenge. For the period 2009-2014, tropical cyclones of non-tropical origin had an average genesis lead time of 27 h for disturbances in the low category of the short-range portion of the TWO; the corresponding lead time for cyclones forming from tropical waves was 66 h. In this case of Fay, global models depicted an inverted trough forming south of Bermuda 4-5 days before genesis but with little additional development. About three days before genesis, the model guidance indicated the possibility of two systems developing from the same non-tropical disturbance that produced Fay, one that would move northward toward Bermuda and the other moving farther northwestward into the western Atlantic. Thus, the numerical guidance offered weak support for subtropical or tropical cyclogenesis at extended lead times. However, the global model guidance within 2-3 days of genesis did show weak low pressure moving northward over the central Atlantic toward Bermuda, but it was assumed that marginally favorable or unfavorable environmental conditions would inhibit significant development.

A verification of NHC official track forecasts for Fay is given in Table 5a. Official forecast track errors were greater than the mean official errors for the previous 5-yr period, with errors about double the long-term mean at 36 h and 48 h. No forecasts verified beyond 48 h. Fay moved farther west and slower than what was predicted. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. No particular model consistently outperformed the official forecast, though the UKMET (UKMI) model generally performed well. However, there were too few cases to verify by 48 h for any meaningful conclusions to be drawn about model performance relative to the official forecasts.

A verification of NHC official intensity forecasts for Fay is given in Table 6a. Official forecast intensity errors were greater than the mean official errors for the previous 5-yr period except at 24 h. The official forecasts underestimated the amount of strengthening that would occur, since strong vertical wind shear was expected to hamper significant intensification. A homogeneous comparison of the official intensity errors with selected guidance models is given

in Table 6b. Decay-SHIPS (DSHP) was the best model and performed well relative to the official forecast at all forecast times except at 12 h, and the intensity model consensus also fared well at 36 h and 48 h. However, the sample size is too low by 48 h to draw any meaningful conclusions about model performance relative to the official forecast.

Watches and warnings associated with Fay are given in Table 7. A tropical storm watch was issued by the Bermuda Weather Service almost 48 h prior to the onset of tropical storm conditions and a tropical storm warning about 24 h beforehand. A hurricane watch was issued about 12 h before hurricane conditions occurred on Bermuda.

ACKNOWLEDGEMENTS

Thanks are extended James Dodgson, Ian Currie, and Kimberly Zuill at the Bermuda Weather Service for providing data and other information about impacts in Bermuda.

References

Harper, B.A., J.D. Kepert, and J.D. Ginger, 2009: Guidelines for Converting Between Various Wind Averaging Periods in Tropical Cyclone Conditions. World Meteorological Organization, 52 pp.

Table 1. Best track for Hurricane Fay, 10-13 October 2014.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
10 / 0000	22.0	61.2	1007	35	low
10 / 0600	22.7	62.4	1006	35	subtropical storm
10 / 1200	23.5	63.3	1005	35	"
10 / 1800	24.3	64.0	1003	40	"
11 / 0000	25.1	64.5	999	50	"
11 / 0600	26.0	65.0	994	55	tropical storm
11 / 1200	27.2	65.3	990	60	"
11 / 1800	28.7	65.4	988	60	"
12 / 0000	30.2	65.2	987	60	"
12 / 0600	31.7	64.9	985	65	hurricane
12 / 0810	32.3	64.7	984	70	"
12 / 1200	33.1	63.9	983	70	"
12 / 1800	33.6	61.9	986	60	tropical storm
13 / 0000	33.9	59.0	990	50	"
13 / 0600					dissipated
12 / 1200	33.1	63.9	983	70	maximum wind and minimum pressure
12 / 0810	32.3	64.7	984	70	landfall on Bermuda

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Fay, 10-13 October 2014.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
12 / 1000	C6FT7	32.5	64.8	320 / 55	994.6
12 / 1800	V7SX3	32.7	64.8	350 / 36	1012.0
12 / 1800	WGAE	36.8	63.7	360 / 40	1010.0
13 / 0000	DGZL	37.2	58.9	020 / 40	1010.1

Table 3. Selected surface observations for Hurricane Fay, 10-13 October 2014

Location and Elevation (m)	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)	
Bermuda						
L.F. Wade International Airport (15.2 m) (TXKF) (32.36N 64.68W)	12/0820	985.1	12/1034	53	71	1.87
Commissioner's Point (45.7 m) (32.329134N 64.832203W)			12/1020	76	107	
Harbour Radio (St. George's) (88.4 m) (32.3803N 64.6825W)					102	
Fort Prospect (70.1 m) (32.299524N 64.765266W)			12/1030	64	102	
St. David's (48.5 m) (32.36378N 64.656138W)			12/1050	69	100	
Causeway (12.2 m) (32.358252N 64.706171W)			12/1103		91	
St. George (Bermuda ESSO Pier) (32.3733N 64.7037W)	12/0712	985.5	12/1012	41	55	
Weather Underground						
Smith's Parish (42.6 m) (ISMITHSP2) (32.319N 64.743W)	12/0810	984.5	12/0955	70	95	
Pembroke (22.8 m) (IPEMBROK5) (32.303N 64.803W)	12/0708	986.5	12/1019	44	50	
Chaingate Hill Devonshire (35 m) (IDEVONSH3) (32.307N 64.749W)	12/0710	986.7	12/1026	57	76	
Gilbert Hill Smith's Parish (59.4 m) (ISMITHSP3) (32.311N 64.739W)	12/0951	985.8		37	48	

^a Date/time is for sustained wind when both sustained and gust are listed.

^b Except as noted, sustained wind averaging periods for Bermuda official sites are 10 min; Weather Underground sites have sustained wind averaging periods of 1 min.

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 (<30%)	36	36
Medium (30%-50%)	18	30
High (>50%)	6	6

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Fay, 10-13 October 2014. 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	35.7	48.9	101.8	134.2			
OCD5	58.7	115.2	174.8	266.7			
Forecasts	9	7	5	3			
OFCL (2009-13)	25.7	41.4	55.0	68.6			
OCD5 (2009-13)	37.2	74.8	118.0	162.5			

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Fay, 10-13 October 2014. 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	39.5	52.7	113.6	75.2			
OCD5	64.1	123.8	177.9	284.9			
GFSI	52.6	77.6	178.4	132.9			
GHMI	40.3	61.9	208.9	144.7			
HWFI	46.8	52.0	104.6	105.3			
UKMI	38.1	50.8	82.2	108.9			
EGRI	39.2	53.9	88.2	120.1			
CMCI	43.4	77.7	130.6	120.0			
NVGI	35.2	62.8	109.2	84.6			
GFNI	41.7	40.0	115.1	217.8			
AEMI	40.3	59.0	158.2	114.1			
FSSE	39.8	51.9	118.8	101.7			
TVCA	40.0	51.7	122.1	156.1			
LBAR	39.5	52.6	59.9	75.2			
NAMI	46.1	92.7	175.3	50.3			
BAMS	56.9	133.5	190.2	276.9			
BAMM	42.7	64.5	95.0	97.2			
BAMD	72.2	109.3	194.1	232.8			
Forecasts	8	6	4	1			

Table 6. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Fay, 10-13 October 2014. 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	7.8	9.3	15.0	16.7			
OCD5	6.4	10.3	11.0	18.0			
Forecasts	9	7	5	3			
OFCL (2009-13)	6.1	10.4	13.4	14.5			
OCD5 (2009-13)	7.7	12.7	16.4	18.8			

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Fay, 10-13 October 2014. 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 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	6.9	7.5	13.8	10.0			
OCD5	5.1	8.3	9.3	15.0			
GHMI	9.9	14.3	15.3	14.5			
HWFI	10.4	13.7	19.0	18.0			
DSHP	7.5	7.2	9.8	8.0			
LGEM	6.0	8.0	10.5	12.0			
FSSE	7.9	11.8	14.0	10.0			
ICON	7.6	10.0	12.5	9.5			
IVCN	7.6	10.0	12.5	9.5			
Forecasts	8	6	4	2			

Table 7. Watch and warning summary for Hurricane Fay, 10-13 October 2014.

Date/Time (UTC)	Action	Location
10 / 1500	Tropical Storm Watch issued	Bermuda
11 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Bermuda
11 / 2100	Hurricane Watch issued	Bermuda
12 / 1500	Tropical Storm Warning discontinued	All
12 / 1500	Hurricane Watch discontinued	All

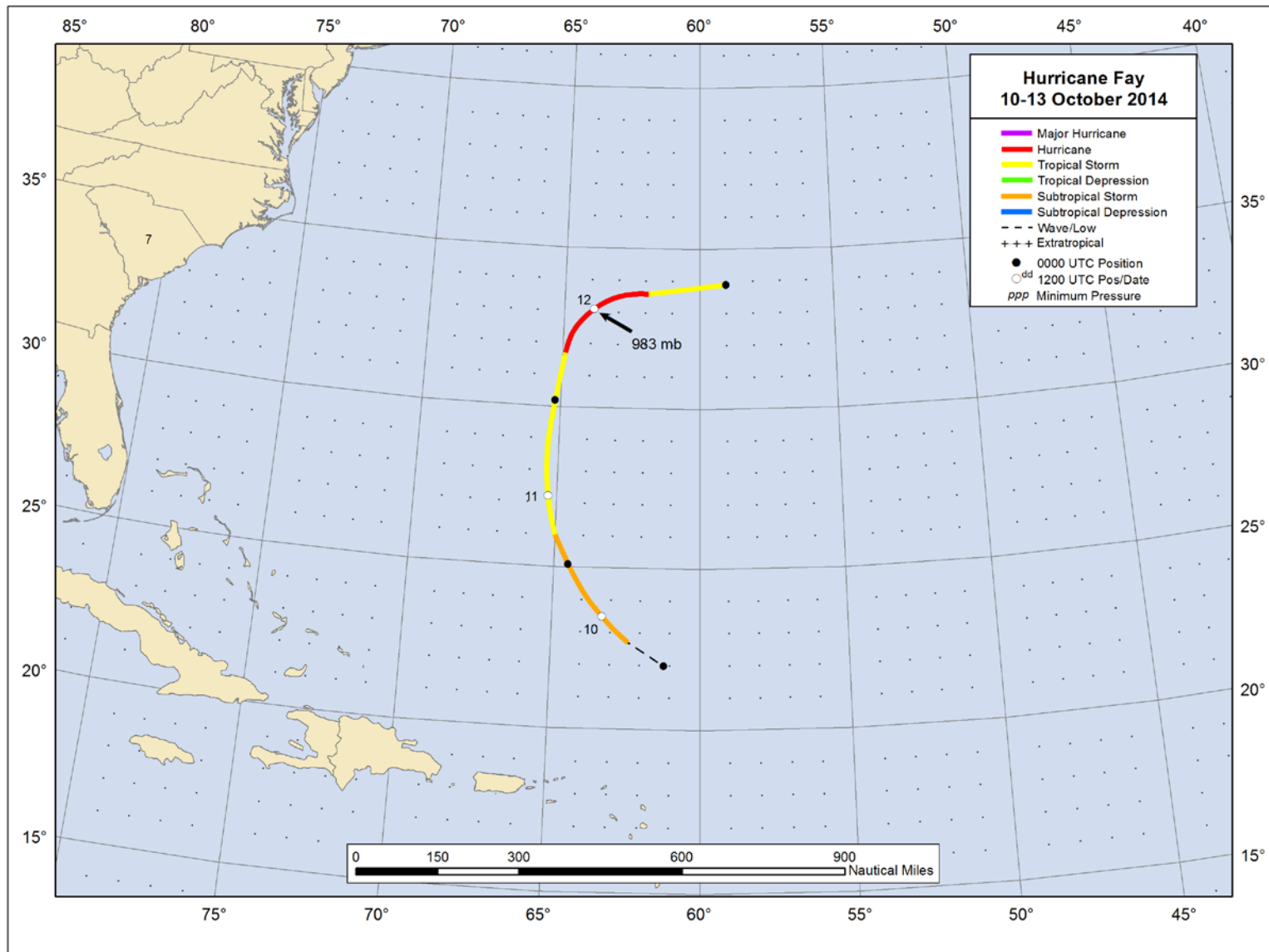


Figure 1. Best track positions for Hurricane Fay, 10-13 October 2014.

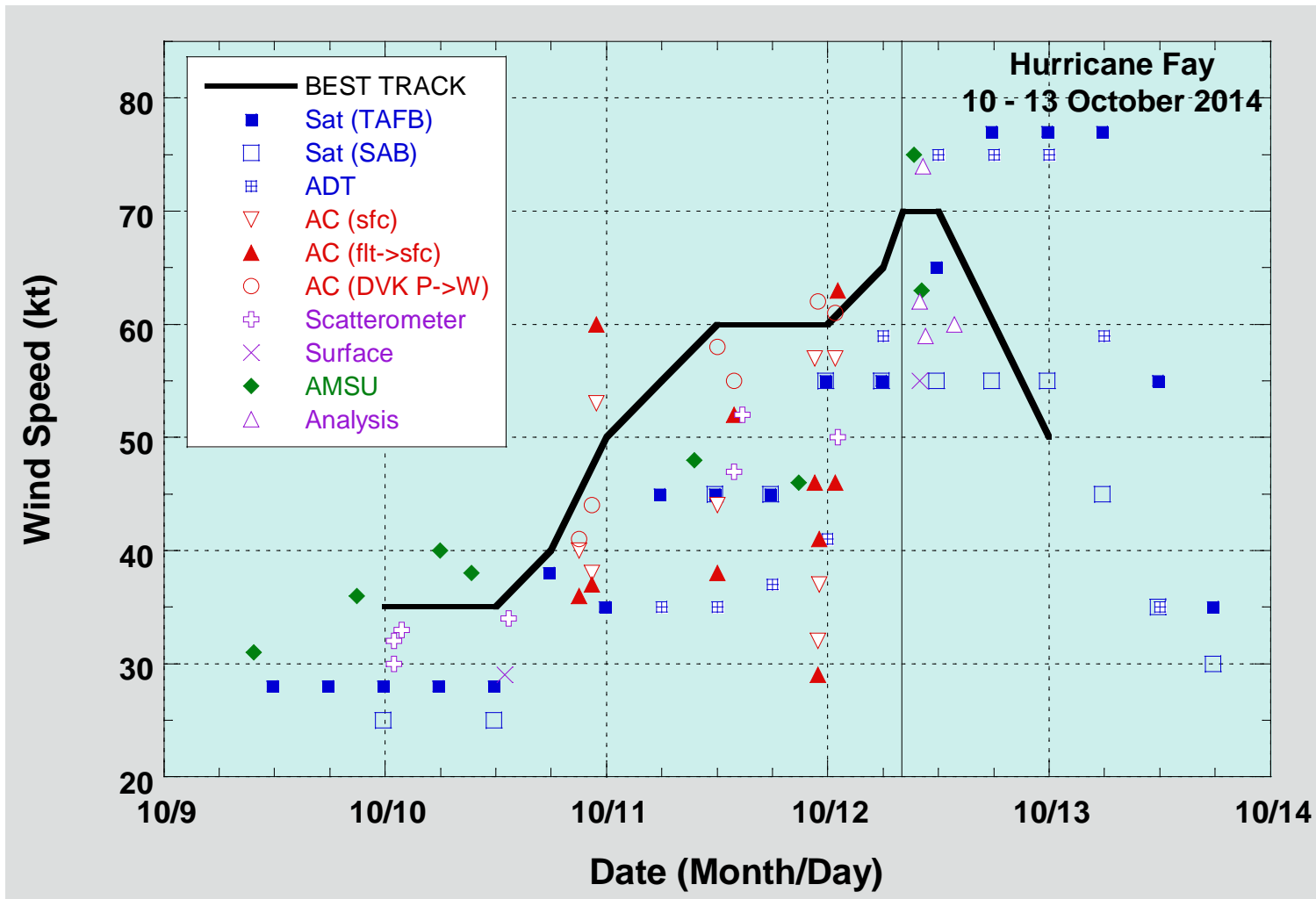


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Fay, 10-13 October 2014. Aircraft observations have been adjusted for elevation using a 90% adjustment factor for observations from 700 mb. Dropwindsonde observations include actual 10 m winds (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 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, and the solid vertical line corresponds to landfall.

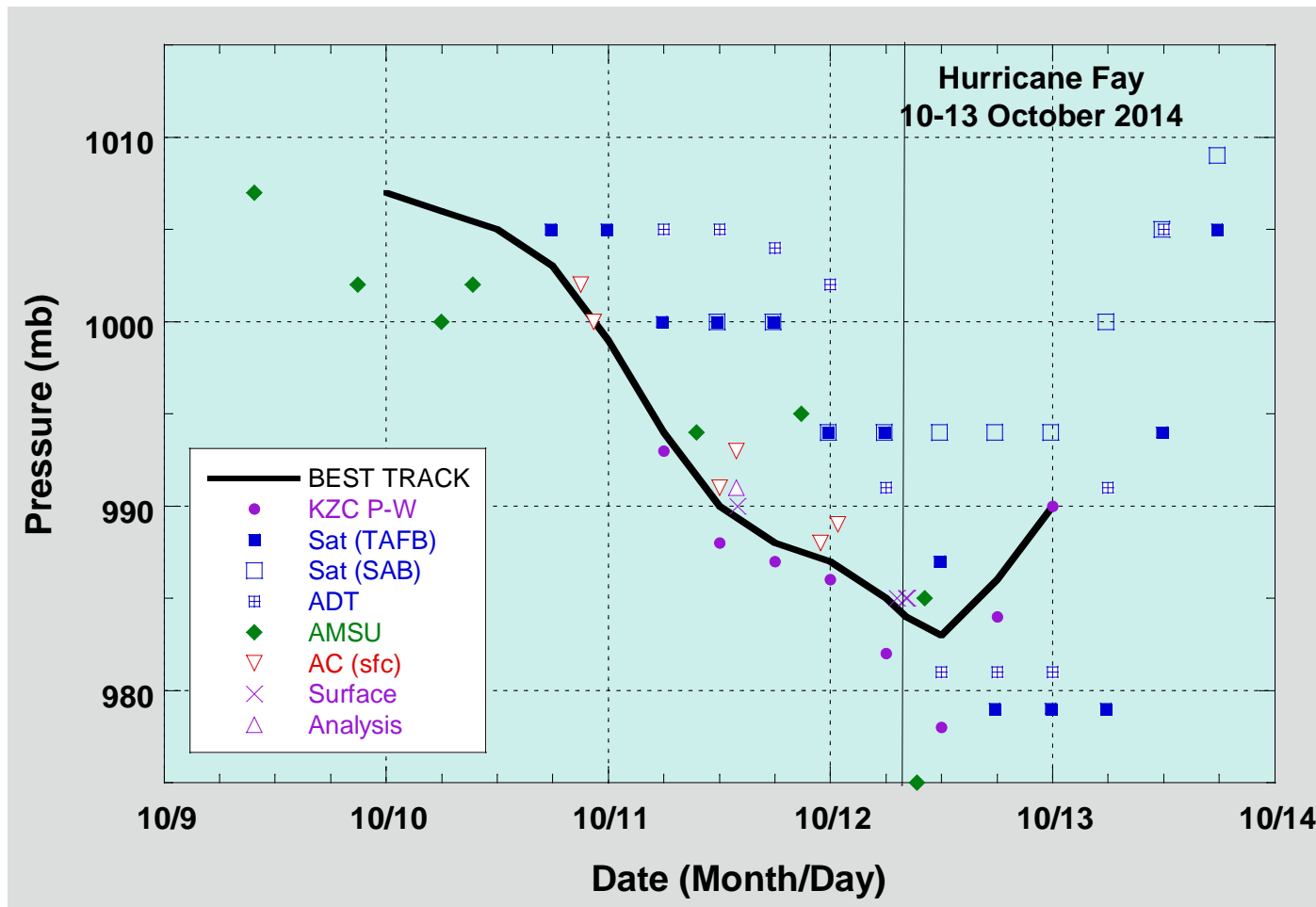


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Fay, 10-13 October 2014. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological 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, and the solid vertical line corresponds to landfall.

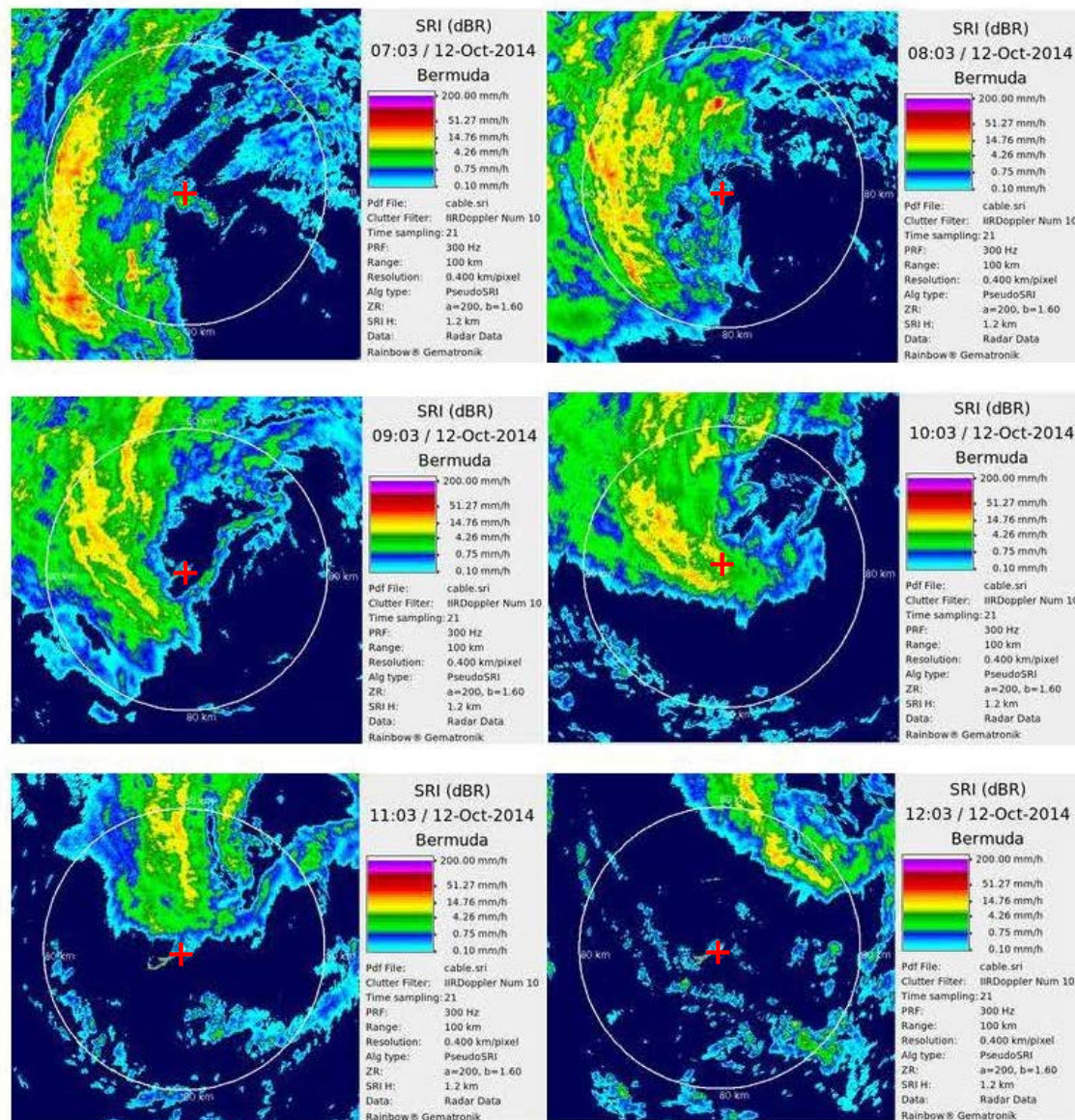


Figure 4. An hourly series of radar images showing Hurricane Fay passing Bermuda early on 12 October. The red cross in each image marks the site of the radar. Images courtesy of the Bermuda Weather Service.

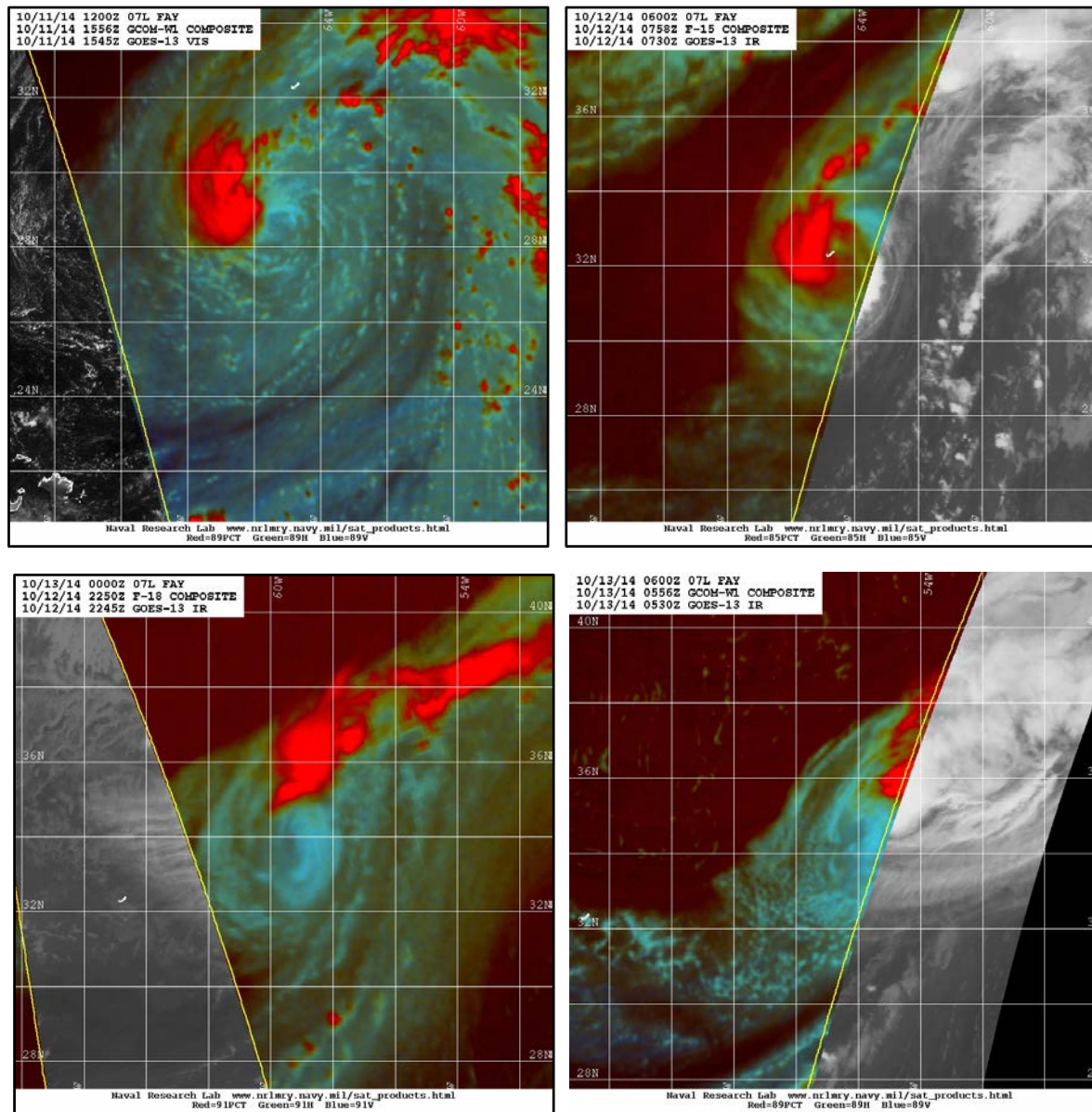


Figure 5. Series of 85-91-GHz microwave images showing the evolution of Fay's cloud pattern as it approached and then passed Bermuda, 11-12 October. Images courtesy of the Naval Research Lab.

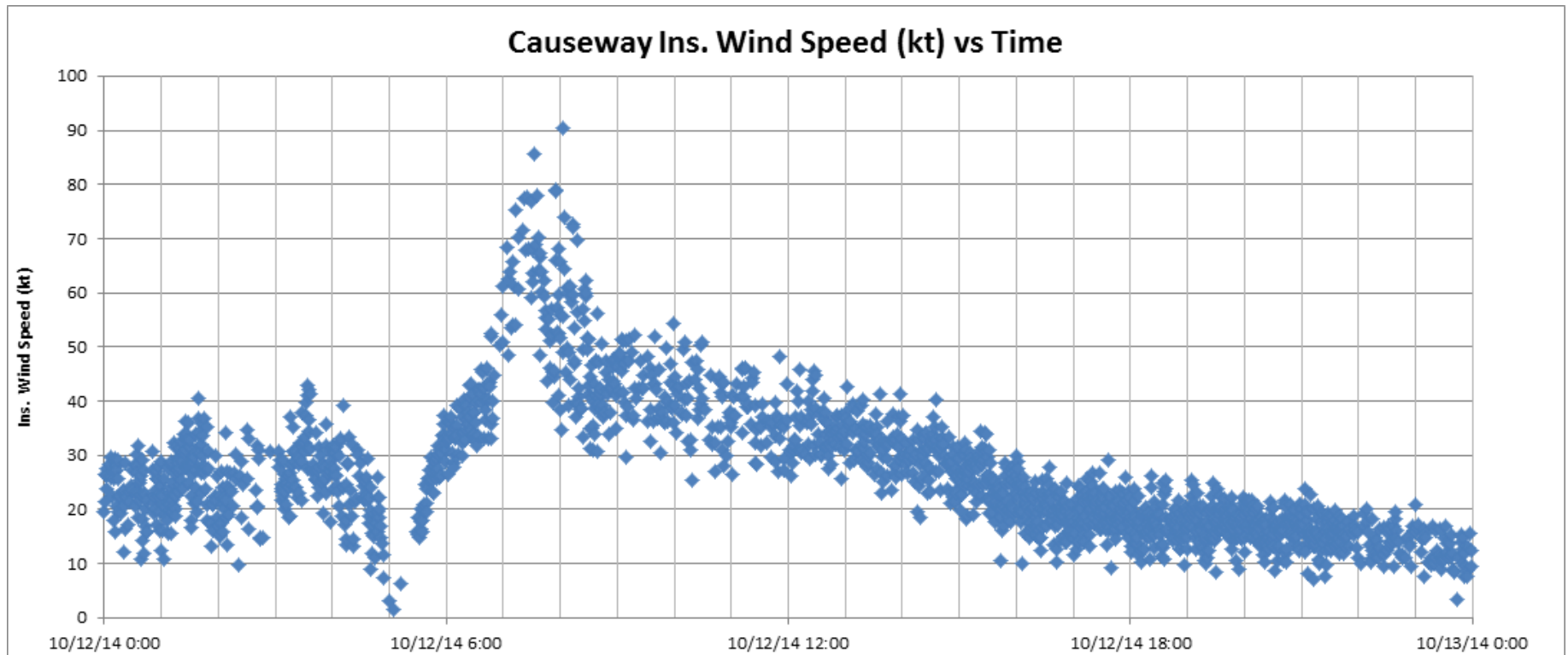


Figure 5. Trace showing wind gusts at the Bermuda Causeway between midnight (local time) 12 and 13 October showing. Image courtesy of the Bermuda Weather Service.

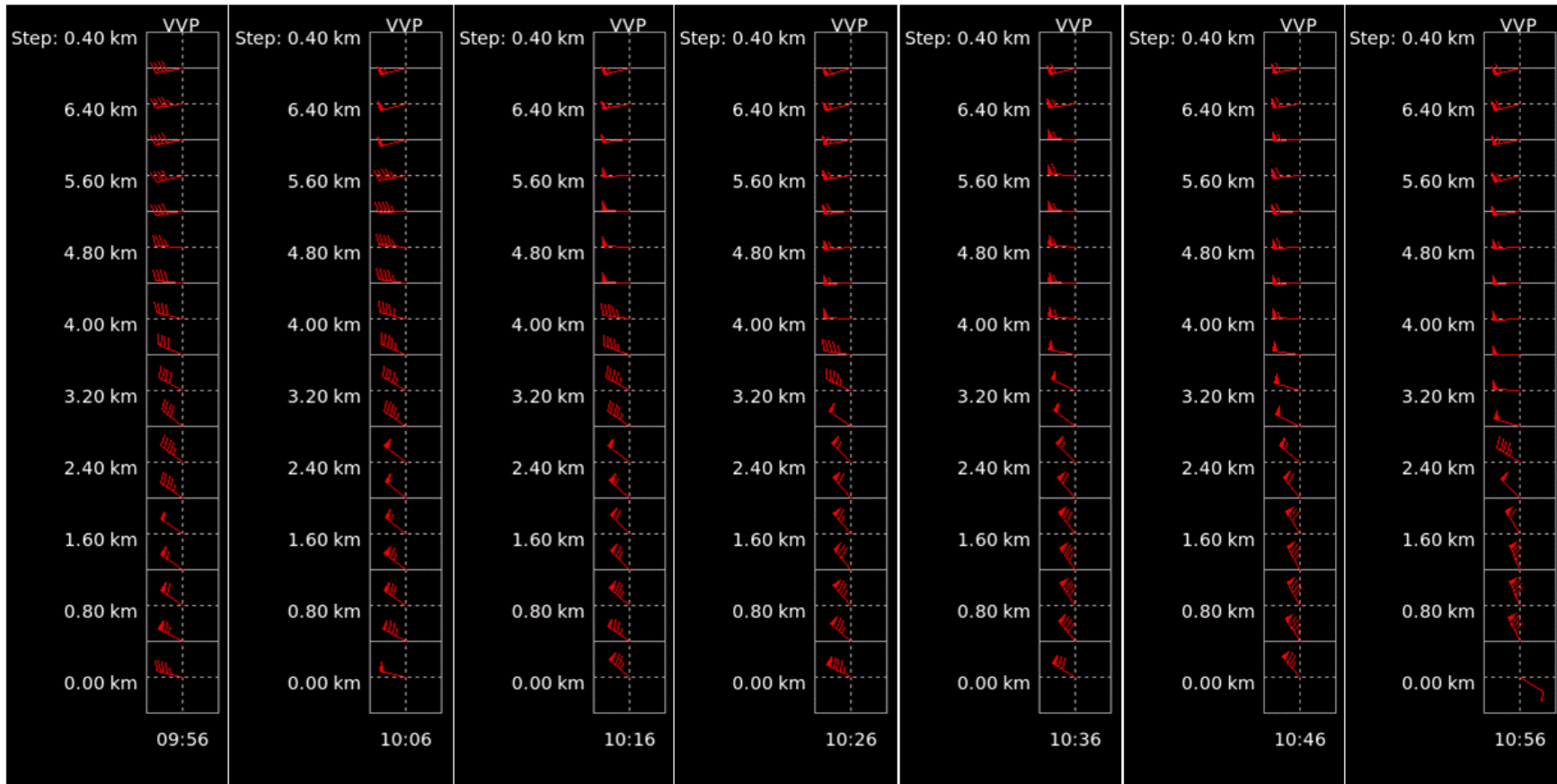


Figure 6. Radar velocity (VVP or velocity volume processing) data with height (km) from 0956 UTC to 1056 UTC 12 October. Image courtesy of the Bermuda Weather Service.