Tropical Cyclone Report
Hurricane Ophelia
(AL162011)
20 September - 3 October 2011

John P. Cangialosi
National Hurricane Center
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Ophelia was a tropical storm when it was near the northern Leeward Islands, and became a category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) when it passed to the east of Bermuda.

a. Synoptic History

Ophelia developed from the interaction of a tropical wave and the Intertropical Convergence Zone (ITCZ). A disturbance formed in the ITCZ on 18 September about 750 n mi west-southwest of the Cape Verde Islands, remaining nearly stationary and changing little in organization during the next couple of days. Meanwhile, a westward-moving tropical wave pushed off the west coast of Africa on 16 September and merged with the ITCZ disturbance late on 19 September. A surface low developed from the merged system around 0600 UTC 20 September about 750 n mi west-southwest of the Cape Verde Islands. Deep convection gradually became organized around a well-defined center on 20 September, and it is estimated that a tropical depression formed around 1800 UTC that day about 1300 n mi east of the Lesser Antilles. The European Space Agency's Advanced Scatterometer (ASCAT) caught the circulation of the cyclone just prior to 0000 UTC 21 September, and these data suggest that the system had strengthened to a 40-kt tropical storm by that time. The "best track" chart of Ophelia'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].

Ophelia strengthened slowly in an environment of moderate southwesterly shear during the next 24 to 36 h, as it moved westward over the tropical Atlantic to the south of a subtropical ridge. Very valuable data from ship *Donaugracht* (PBSY***)*** and NOAA buoy 41041, along with scatterometer data, indicate that Ophelia reached its first peak intensity of 55 kt around 0600 UTC 22 September, when centered about 850 n mi east of the Lesser Antilles. It should be mentioned that these ground-truth data were notably higher than the concurrent satellite intensity estimates (Fig. 2). Southwesterly shear increased to 20-25 kt later on 22 September, and that caused the cyclone to weaken. Satellite images indicate that the low-level center of Ophelia became exposed to the west of a shrinking area of deep convection by 0000 UTC 23 September. Ophelia is estimated to have weakened to 40 kt 6 h later, when centered about 600 n mi east of the Lesser Antilles. Deep convection, however, increased again during the afternoon of 23 September, and reports from an Air Force Reserve reconnaissance aircraft indicate that Ophelia's intensity increased to 50 kt around 1800 UTC that day. The cyclone, which was now moving

[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.

west-northwestward to northwestward, did not maintain that intensity for long. Ophelia gradually lost organization, and this time weakened steadily over the next couple of days as it approached the northern Leeward Islands. The center once again became exposed to the west of the deep convection around 0600 UTC 25 September, and Ophelia degenerated into a remnant low pressure system about 6 h later when it was located about 180 n mi east of the northern Leeward Islands. Conventional satellite and microwave data indicate that the remnant circulation dissipated by 0000 UTC 26 September.

Although the low-level center of the tropical cyclone had dissipated, the associated deep convection lingered. In fact, a mid-level circulation was evident within the convection only a few hours after the cyclone dissipated. Surface observations and ASCAT data indicate that the mid-level circulation gradually built downward, and a highly elongated surface circulation developed around 0000 UTC 27 September. The surface center developed sufficient definition by 1200 UTC that day for the system to be considered a tropical depression about 170 n mi east of the northern Leeward Islands. Since the depression formed within the deep convection associated with the remnants of Ophelia, the same name was retained. An Air Force Reserve reconnaissance aircraft investigated the depression 6 h later and indicated that the maximum wind speed was near 25 kt. Ophelia moved slowly northwestward over the next day or so as it gradually gained strength, becoming a tropical storm again around 0600 UTC 28 September about 130 n mi east of the northern Leeward Islands.

After regaining tropical storm status, Ophelia strengthened steadily, and even rapidly for a period, as it turned northward on the western periphery of the subtropical high. Ophelia became a hurricane around 1800 UTC 29 September, when located about 200 n mi north of the northern Leeward Islands, and then reached major hurricane status only 24 h later when it was centered almost midway between the northern Leeward Islands and Bermuda. As Ophelia approached Bermuda, the eye became more distinct and deep convection gained symmetry. It is estimated that Ophelia reached its peak intensity of 120 kt around 0000 UTC 2 October, when it was located about 120 n mi east-northeast of Bermuda. The wind field associated with the major hurricane was compact however, such that winds on Bermuda did not even reach tropical storm force.

Ophelia accelerated north-northeastward after reaching its peak intensity and weakened rapidly when it encountered strong southwesterly shear and moved over much cooler waters. The cyclone fell below major hurricane status 18 h after the time of its peak intensity, and weakened to a tropical storm by 0600 UTC 3 October when located about 200 n mi west-southwest of Cape Race, Newfoundland. Ophelia lost its tropical characteristics just before it made landfall over southern Newfoundland around 1000 UTC 3 October. The extratropical low turned east-northeastward while it weakened over the North Atlantic and became absorbed by a larger weather system around 1800 UTC 4 October.

A sequence of visible satellite images (Fig. 4) shows the evolution of Ophelia.

b. Meteorological Statistics

Observations in Ophelia (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 (CIMSS). Observations also include flight-level and stepped frequency microwave radiometer (SFMR) from flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command (53WRS). Data and imagery from NOAA polar-orbiting satellites, including the Advanced Microwave Sounder Unit (AMSU) intensity estimates from CIMSS, the NASA Tropical Rainfall Measuring Mission (TRMM) and Aqua, the ASCAT, and Defense Meteorological Satellite Program (DMSP) satellites, among others, and radar observations from Bermuda were also useful in constructing the best track of Ophelia.

The estimated peak intensity of Ophelia, 120 kt at 0000 UTC 2 October, is based on a blend of objective (ADT) and subjective Dvorak technique estimates.

Ship and marine platform reports of winds of tropical storm force associated with Ophelia are given in Table 2, and selected surface observations from data buoys are given in Table 3. Surface observations proved to be extremely valuable in tracking Ophelia. The eye of Ophelia passed directly over NOAA buoy 41049 at 0830 UTC 1 October. The buoy reported a maximum 1-min wind of 84 kt with a gust to 101 kt in the northern eyewall and a minimum pressure of 952.8 mb. The eye of Ophelia also passed very near drifting buoys 41982 and 41972. The minimum pressure reported by buoy 41982 was 959.7 mb at 1330 1 October. Buoy 41972 reported a minimum pressure of 962.6 mb at 0930 UTC 2 October.

c. Casualty and Damage Statistics

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

d. Forecast and Warning Critique

The genesis of Ophelia was well anticipated. The disturbance that Ophelia originated from was introduced with a low probability of formation (less than 30%) in the Atlantic Tropical Weather Outlook (TWO) at 0000 UTC 18 September, 66 h prior to formation. The probability was raised to medium (30-50%) at 0000 UTC 19 September and to the high category (greater than 50%) 6 h after that, which was 36 h before the tropical cyclone developed. The reformation of Ophelia was also forecast reasonably well. The remnants of Ophelia were introduced in the TWO 36 h before the tropical cyclone re-developed. The probability was raised to the medium category 18 h before genesis and to the high category 12 h before Ophelia regenerated into a tropical depression.

A verification of NHC official track forecasts for Ophelia is given in Table 4a. Official forecast track errors were near or lower than the previous 5-yr mean from 12 to 48 h, but significantly higher than the previous 5-yr mean at 96 and 120 h. The climatology and

persistence model (OCD5) errors for Ophelia were also much higher than the 5-yr mean from that model at 96 and 120 h, which indicates that the track of this tropical cyclone was harder than average to predict at the longer range forecast times. The main reasons for the large errors at 96 and 120 h were the unanticipated dissipation of Ophelia and regeneration to the southeast of the original cyclone. Fig. 5 illustrates these points using a single forecast about 2 days prior to the first dissipation of Ophelia. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. The official forecast outperformed virtually all of the model guidance from 12 to 48 h; however, several of the models bested the official forecast at 96 and 120 h.

A verification of the NHC official intensity forecasts for Ophelia is given in Table 5a. Official forecast errors for Ophelia were lower than previous 5-yr mean at all forecast times. The OCD5 errors were higher than the previous 5-yr mean from that model, indicating that Ophelia's intensity was difficult to forecast and that the official forecasts were quite skillful. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. The only model that beat the official forecast at any time was the GFDL (GHMI), which outperformed the official forecast at 12 and 24 h. The official forecasts had much lower errors than several of the models from 72 to 120 h.

There were no coastal tropical cyclone warnings issued for Ophelia. The associated watches are given in Table 6.

Table 1. Best track for Hurricane Ophelia, 20 September – 3 October 2011. Positions and pressures given during the disturbance stage are representative values for the low-level vorticity center.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
20 / 0600	11.6	37.0	1008	25	low
20 / 1200	11.9	37.7	1007	25	"
20 / 1800	12.2	38.6	1007	30	tropical depression
21 / 0000	12.5	39.7	1005	40	tropical storm
21 / 0600	12.7	41.1	1004	45	"
21 / 1200	12.9	42.6	999	50	"
21 / 1800	13.1	44.1	999	50	"
22 / 0000	13.3	45.2	998	50	"
22 / 0600	13.5	46.3	993	55	"
22 / 1200	13.7	47.3	993	55	"
22 / 1800	13.9	48.3	997	50	"
23 / 0000	14.1	49.4	1000	45	"
23 / 0600	14.4	50.5	1003	40	"
23 / 1200	14.7	51.7	1003	45	"
23 / 1800	15.2	52.9	1001	50	"
24 / 0000	15.8	54.0	1004	45	"
24 / 0600	16.5	54.8	1005	45	"
24 / 1200	17.2	55.9	1005	45	"
24 / 1800	17.6	57.0	1007	40	"
25 / 0000	17.9	58.0	1008	40	"
25 / 0600	18.2	59.0	1008	35	"
25 / 1200	18.4	59.8	1010	30	low
25 / 1800	18.6	60.5	1012	30	"
26 / 0000	18.5	60.8	1012	25	disturbance
26 / 0600	18.3	60.7	1012	25	"
26 / 1200	18.0	60.5	1012	25	"
26 / 1800	17.8	60.2	1012	25	"
27 / 0000	17.6	59.9	1012	25	"
27 / 0600	17.6	59.5	1012	25	"
27 / 1200	17.8	59.3	1010	25	tropical depression
27 / 1800	18.0	59.4	1009	25	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 0000	18.1	59.5	1009	30	"
28 / 0600	18.2	59.6	1005	40	tropical storm
28 / 1200	18.4	59.8	1001	40	"
28 / 1800	18.7	60.1	1001	45	"
29 / 0000	19.1	60.5	995	50	"
29 / 0600	19.6	60.9	995	55	"
29 / 1200	20.2	61.4	991	55	"
29 / 1800	21.0	61.9	987	65	hurricane
30 / 0000	21.6	62.3	982	70	"
30 / 0600	22.4	62.7	971	85	"
30 / 1200	23.4	63.0	966	95	"
30 / 1800	24.6	63.3	959	100	"
01 / 0000	25.9	63.3	955	105	"
01 / 0600	27.3	63.2	951	105	"
01 / 1200	28.9	63.1	948	105	"
01 / 1800	30.7	62.9	946	110	"
02 / 0000	32.8	62.5	940	120	"
02 / 0600	35.0	62.1	945	110	"
02 / 1200	37.4	61.6	951	105	"
02 / 1800	40.1	60.8	960	90	"
03 / 0000	42.8	59.6	972	70	"
03 / 0600	45.4	57.6	980	60	tropical storm
03 / 1000	46.9	55.4	990	60	extratropical
03 / 1200	47.4	54.0	994	50	"
03 / 1800	48.9	49.2	994	45	"
04 / 0000	49.9	43.6	994	40	"
04 / 0600	50.6	37.8	996	40	"
04 / 1200	51.3	31.9	996	40	"
04 / 1800					dissipated
02 / 0000	32.8	62.5	940	120	minimum pressure and maximum wind

Table 2. Selected ship observations with winds of at least 34 kt for Hurricane Ophelia, 20 September – 3 October 2011.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
21 / 1200	PBSY	14.0	40.8	180 / 52	1013.2
02 / 1800	WAHV	37.2	58.0	190 / 35	1015.6
03 / 0000	WAHK	41.3	57.2	180 / 35	1013.8
03 / 0000	CFO383	43.9	60.2	030 / 35	1001.1

Table 3. Selected surface observations for Hurricane Ophelia, 20 September – 3 October 2011.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed		
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)
Buoys					
41041 (14.2 N 46.0 W)	22/0633	1003.4	22/0620	54	70
41040 (14.5 N 53.0 W)	23/1757	1007.1	23/0924	30	40
41049 (27.5 N 63.0 W)	01/0750	952.8	01/0850	84	101
41982 (29.5 N 62.9 W)	01/1330	959.7			
41972 (36.9 N 61.7 W)	02/0930	962.6			

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

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Ophelia, 20 September – 3 October 2011. Mean errors for the 5-yr period 2006-10 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 (Ophelia)	**30.1**	**45.0**	**64.6**	90.2	169.7	288.8	420.5
OCD5 (Ophelia)	45.2	88.6	154.1	214.2	340.1	475.5	536.7
Forecasts	37	35	33	31	27	23	21
OFCL (2006-10)	31.0	50.6	69.9	89.5	133.2	174.2	214.8
OCD5 (2006-10)	47.7	98.3	156.4	218.1	323.3	402.2	476.1

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Ophelia, 20 September – 3 October 2011. 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	28.9	44.6	72.2	107.6	210.6	358.9	471.9
OCD5	47.6	94.5	183.2	260.8	416.1	494.9	516.5
GFSI	**26.0**	49.0	81.5	128.2	232.0	**327.0**	**366.1**
GHMI	37.9	73.5	109.9	162.4	257.2	393.7	528.1
HWFI	48.2	86.3	106.1	144.0	221.6	**318.2**	**367.4**
GFNI	38.4	72.3	118.6	176.6	295.5	467.1	568.2
NGPI	40.8	74.8	124.6	186.3	331.0	503.7	634.6
EGRI	38.2	63.4	86.7	123.0	**192.1**	**320.6**	**399.3**
EMXI	31.1	48.5	77.8	**99.0**	**187.6**	**298.7**	**399.2**
CMCI	42.4	83.3	131.9	197.6	319.7	489.6	615.3
FSSE	31.9	48.2	78.9	116.5	**203.1**	380.2	498.7
TCON	**28.2**	52.2	81.7	120.1	**196.9**	**328.4**	**415.0**
TCCN	28.9	50.5	79.0	117.4	**193.7**	**315.8**	**408.8**
TVCA	29.7	52.1	80.0	114.9	**185.4**	**316.1**	**401.0**
TVCC	29.1	50.1	79.7	118.9	**199.3**	**321.2**	**407.4**
GUNA	29.7	51.8	82.5	124.5	212.7	**352.2**	**446.6**
LBAR	35.2	63.4	101.8	142.9	**196.6**	**245.5**	**282.0**
BAMS	46.9	83.4	137.0	202.3	366.6	541.4	600.5
BAMM	33.6	64.6	111.8	169.1	291.2	380.9	**355.4**
BAMD	48.2	87.4	128.7	177.8	270.1	**351.2**	**371.6**
Forecasts	23	22	20	19	16	12	10

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Ophelia, 20 September – 3 October 2011. Mean errors for the 5-yr period 2006-10 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 (Ophelia)	**6.6**	**10.7**	**12.6**	**13.9**	**16.7**	**15.2**	**13.6**
OCD5 (Ophelia)	8.9	13.9	18.7	24.9	33.0	35.2	31.1
Forecasts	37	35	33	31	27	23	21
OFCL (2006-10)	7.2	11.0	13.2	15.1	17.2	17.9	18.7
OCD5 (2006-10)	8.5	12.3	15.4	17.8	20.2	21.9	21.7

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Ophelia, 20 September – 3 October 2011. 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	6.4	11.0	13.1	14.4	16.3	13.4	16.8
OCD5	9.2	15.1	20.9	26.0	32.0	30.6	32.7
GHMI	**5.3**	**10.0**	13.7	18.0	22.5	29.4	39.0
HWFI	6.4	11.6	14.0	18.5	22.9	20.0	23.5
GFNI	7.3	11.3	14.5	18.5	22.0	29.5	27.5
FSSE	6.9	11.7	15.0	17.6	23.1	24.7	20.7
DSHP	8.5	13.3	16.4	18.0	19.3	16.0	21.5
LGEM	7.8	13.3	17.7	20.0	20.0	16.2	22.4
ICON	6.8	11.5	14.6	17.7	19.8	16.6	20.8
IVCN	6.6	11.1	14.1	17.4	20.0	18.9	21.0
Forecasts	32	30	26	25	20	16	14

Table 6. Watch and warning summary for Hurricane Ophelia, 20 September – 3 October 2011.

Date/Time (UTC)	Action	Location
29 / 2100	Tropical Storm Watch issued	Bermuda
1 / 2100	Tropical Storm Watch issued	Avalon Peninsula of Newfoundland
2 / 0000	Tropical Storm Watch discontinued	Bermuda
3 / 1500	Tropical Storm Watch discontinued	Avalon Peninsula of Newfoundland

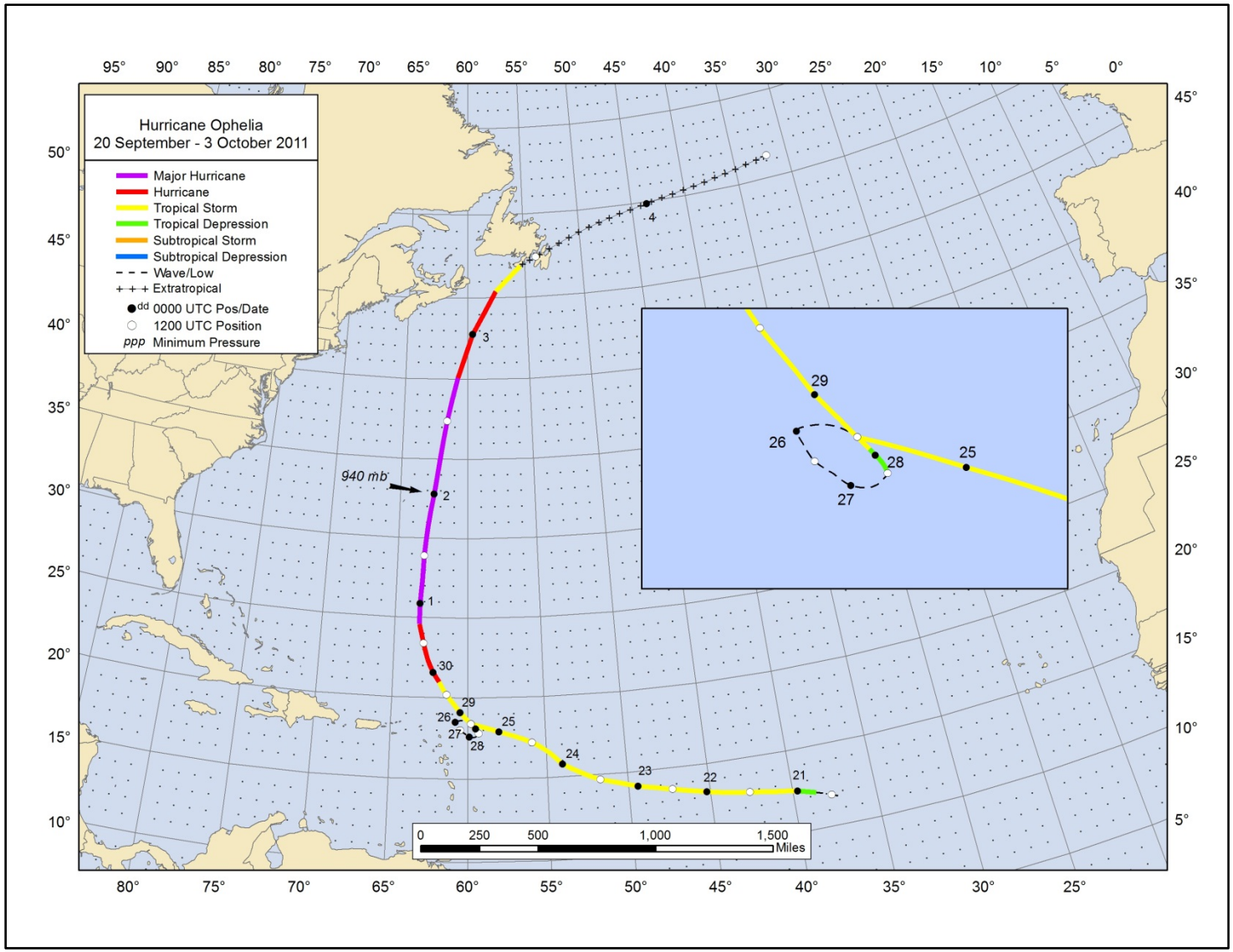

Figure 1. Best track positions for Hurricane Ophelia, 20 September – 3 October 2011. Track during the extratropical stage is based on analyses from the NOAA Ocean Prediction Center. Inset shows detail of Ophelia's reformation.

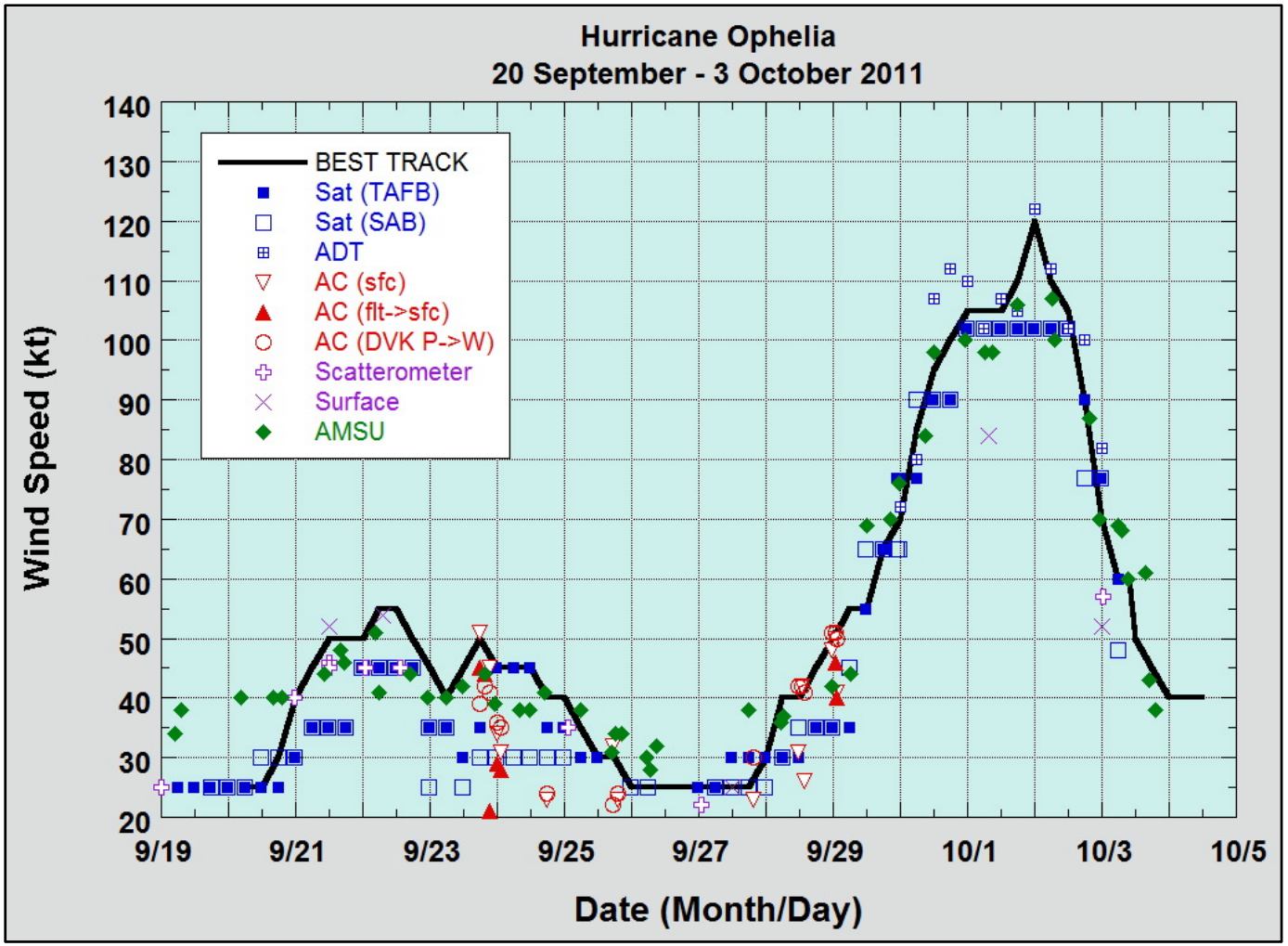

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Ophelia, 20 September – 3 October 2011. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. ADT points represent linear averages of UW-CIMSS Advanced Dvorak Technique estimates over a 3-h period centered on the nominal observation time. AMSU intensity estimates are from the UW-CIMSS technique. Dashed vertical lines correspond to 0000 UTC.

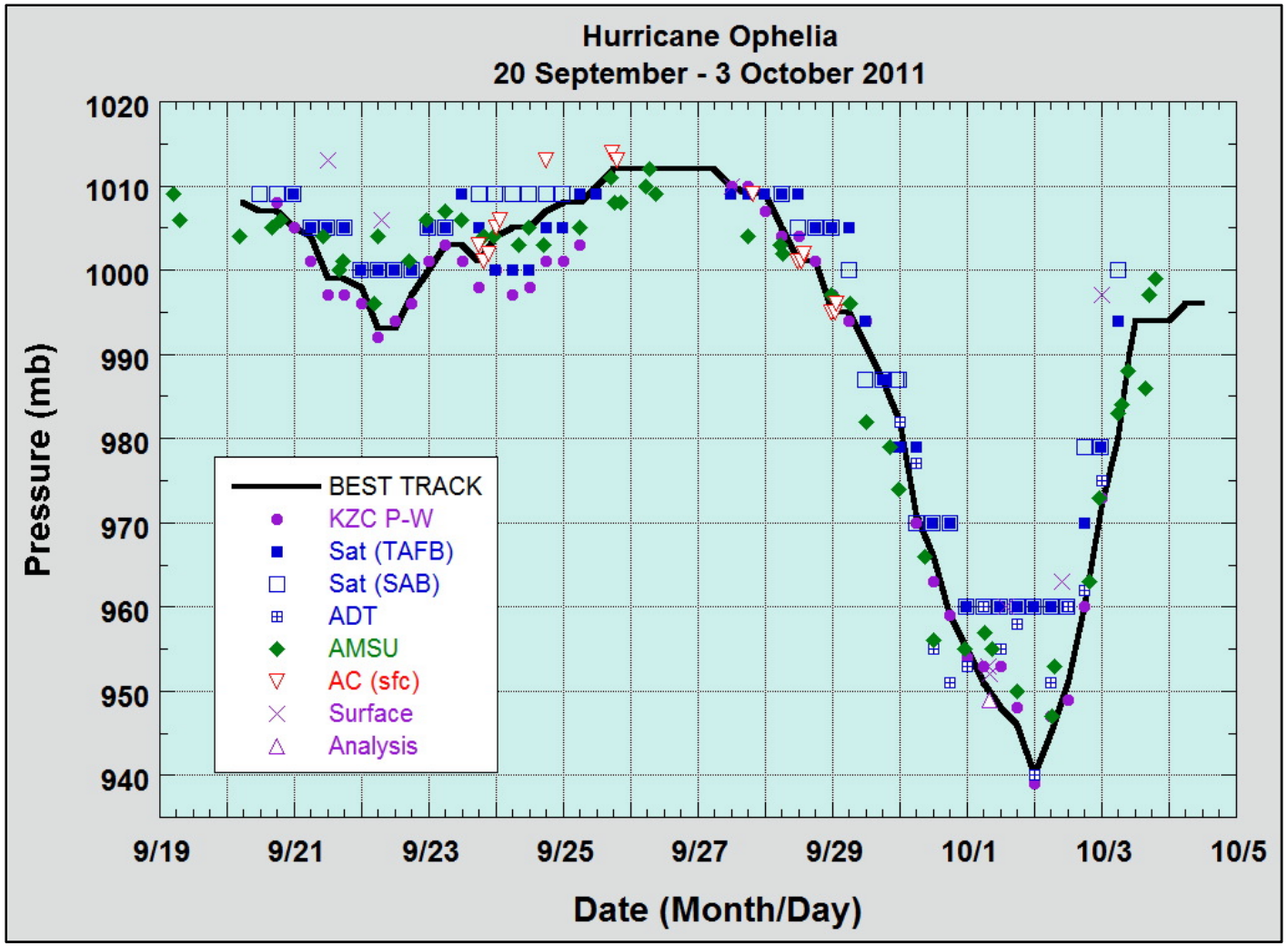

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Ophelia, 20 September – 3 October 2011. ADT points represent linear averages of UW-CIMSS Advanced Dvorak Technique estimates over a 3-h period centered on the nominal observation time. AMSU intensity estimates are from the UW-CIMSS technique. KZC P-W refers to pressure estimates using the Knaff-Zehr-Courtney pressure-wind relationship.

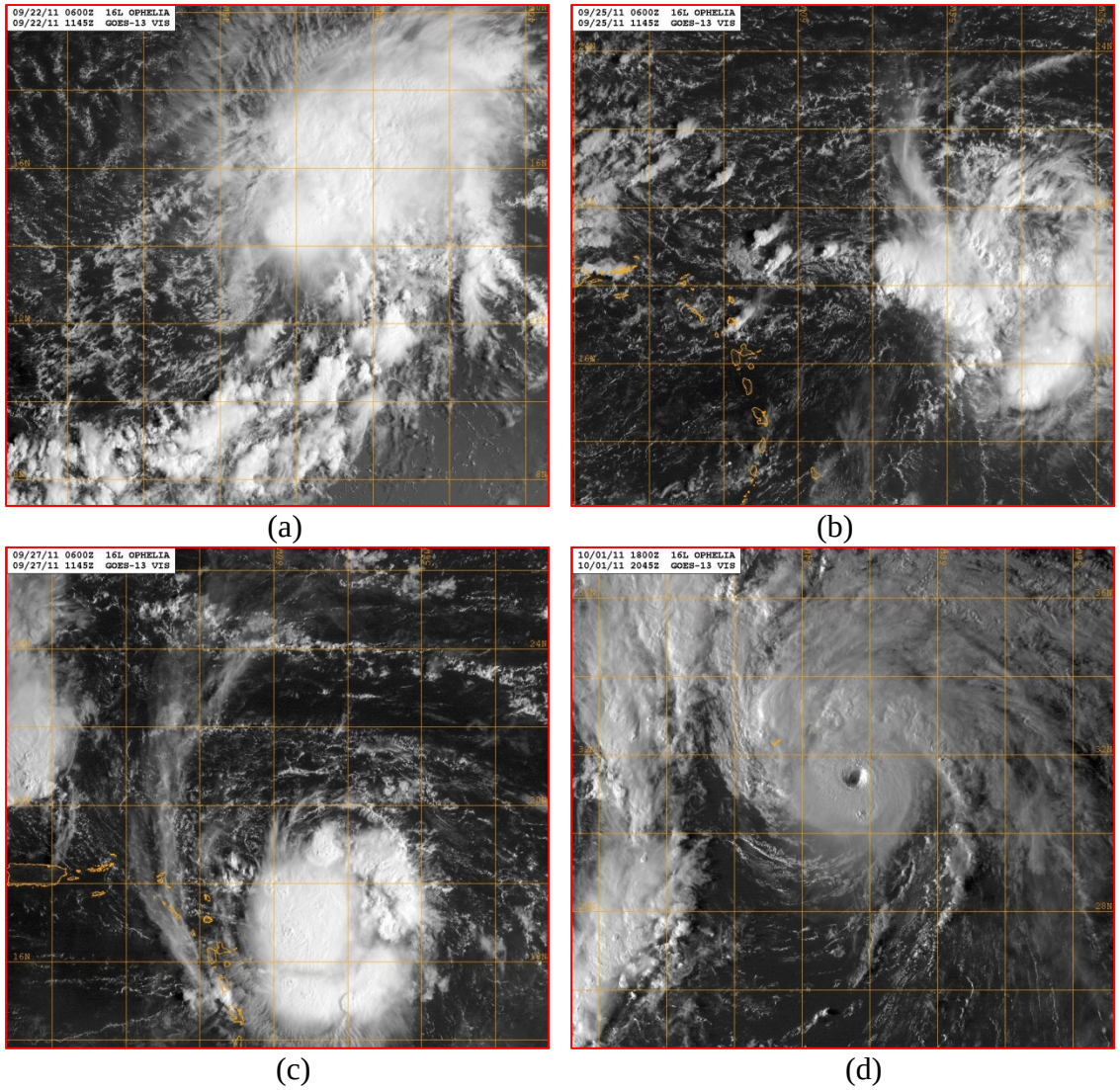

Figure 4. Visible satellite images of Ophelia, 20 September - 3 October 2011, as (a) a tropical storm at 1145 UTC 22 September, (b) a remnant low at 1145 UTC 25 September, (c) a tropical depression at 1145 UTC 27 September, and (d) a major hurricane at 2045 UTC 1 October. Images courtesy of the United States Naval Research Laboratory.

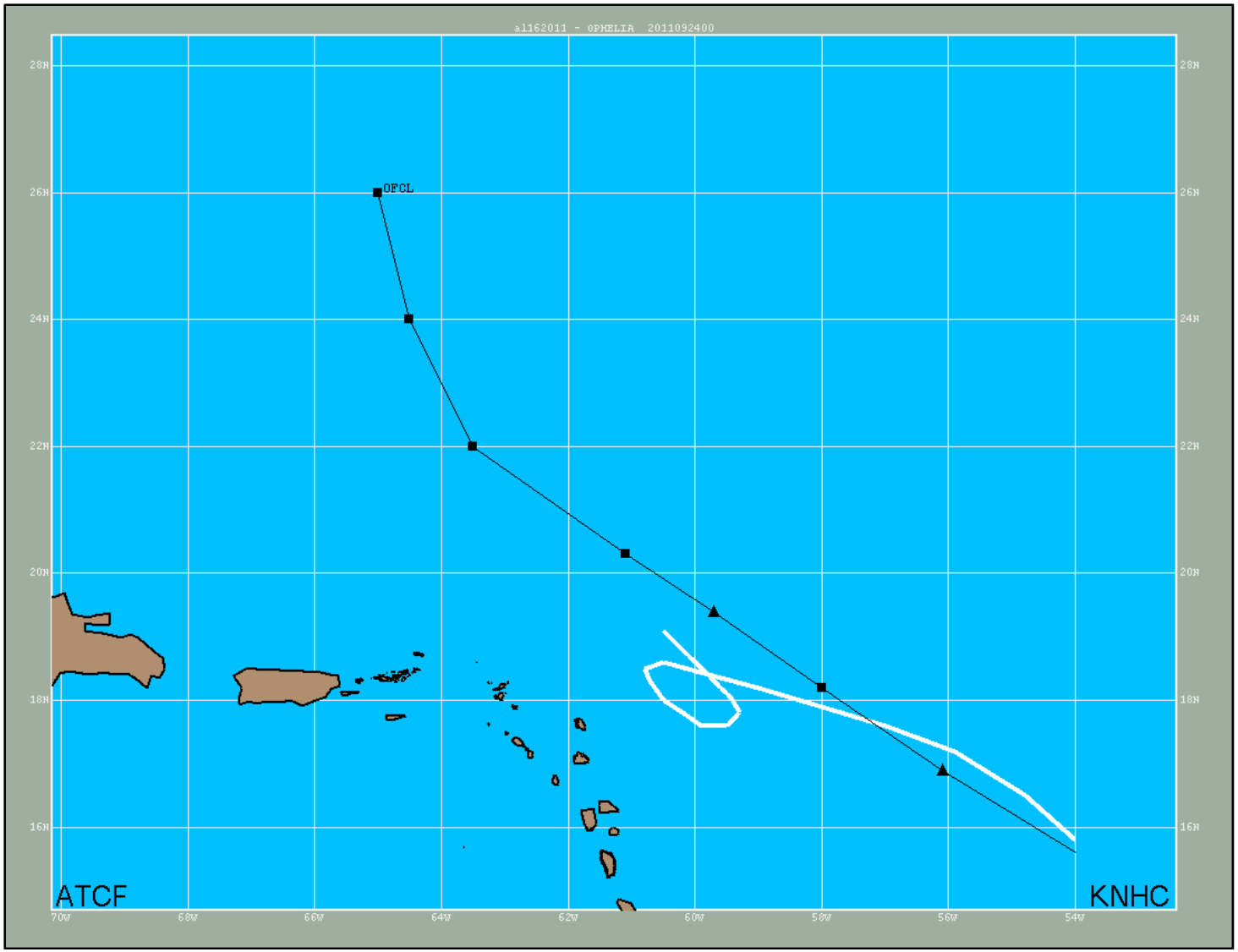

Figure 5. Official 5-day track forecast for Ophelia issued at 0000 UTC 24 September 2011 (black line) and the corresponding best track (white line).