



# NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

## HURRICANE OPHELIA (AL172017)

9–15 October 2017

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MODIS SATELLITE IMAGE OF OPHELIA AT APPROXIMATELY 1500 UTC 16 OCTOBER 2017, ABOUT 3 HOURS AFTER IT MADE LANDFALL OVER SOUTHWESTERN IRELAND AS A POWERFUL EXTRATROPICAL CYCLONE (IMAGE COURTESY NASA).

Ophelia was a category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that spent its entire lifetime over the far eastern Atlantic Ocean, becoming the farthest-east major hurricane observed in the satellite era. After becoming a post-tropical/extratropical cyclone, Ophelia produced hurricane-force wind gusts over much of Ireland and the United Kingdom, resulting in considerable property damage and loss of life.

# Hurricane Ophelia

9–15 OCTOBER 2017

## SYNOPTIC HISTORY

Ophelia's origin was non-tropical. A vigorous mid- to upper-level trough amplified over the central subtropical Atlantic Ocean during the period of 1–5 October. The trough was accompanied by strong directional and speed divergence on the east side of the system, which caused surface pressures to decrease over a large area. By 1200 UTC 3 October, a broad surface low pressure system had formed along a stationary frontal zone about 400 n mi west of the northwestern Azores. The low moved southwestward on 4 October and turned southward the next day. A large radius of maximum winds (RMW) of more than 100 n mi had formed in conjunction with the low when it was located about 700 n mi southwest of the Azores early on 6 October. Initially, only shallow, weak convection developed in association with the low, and an associated long, curved cloud band had the appearance of a cold-core, extratropical low pressure system. However, the warm water beneath the cyclone was anomalously warm, characterized by sea-surface temperatures (SST) near 27°C, which gradually eroded the associated frontal systems by 1200 UTC 7 October. Over the next 48 h while moving little, the cyclone attempted to acquire subtropical characteristics, but organized deep convection was unable to persist near the well-defined low-level center due to entrainment of very dry mid-level air. However, each short-lived convective burst helped to spin up the wind field, resulting in the low becoming a gale area by early on 8 October. Convection steadily increased near the center of the low over the next 24 h, and it is estimated that a tropical storm formed by 0600 UTC 9 October when the system was located about 760 n mi west-southwest of the Azores. 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<sup>1</sup>.

Trapped between a subtropical ridge to the south and a mid-latitude ridge to the north, Ophelia meandered for the next two days in the same general area more than 700 n mi southwest of the Azores. During this time, the cyclone steadily strengthened over SSTs of about 26.5°C and within relatively low vertical wind shear conditions, becoming a 55-kt tropical storm by early on 11 October. Although the SSTs would generally be marginal for tropical cyclone formation and intensification, the ambient environment in which Ophelia formed was characterized by mid- and upper-level temperatures that were 2°–3°C cooler than average, resulting in steep tropospheric lapse rates that supported the development of vigorous deep convection. Ophelia turned toward the southeast later that day and continued to strengthen, becoming a hurricane by 1800 UTC when the cyclone was located about 660 n mi southwest of the Azores.

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<sup>1</sup> 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.

On 12 October, a broad mid-latitude trough moved east-southeastward out of Canada and reached the far northern Atlantic by 14 October, causing erosion of the ridge to the north of Ophelia. The southwesterly flow ahead of the trough and associated cold front resulted in the cyclone gradually turning toward the northeast, followed by steady acceleration with forward speeds increasing from near 5 kt on 12 October to around 20 kt on 14 October. During this 48-h period, Ophelia experienced two periods of strengthening that were punctuated by one short-lived period of weakening. The first intensification cycle continued the previous slow but steady strengthening process that began on 9 October, resulting in Ophelia reaching its first peak intensity of 90 kt around 0000 UTC 13 October when the hurricane was centered about 570 n mi southwest of the Azores. The cyclone maintained its 90-kt intensity for another 6 h, after which the vertical wind shear increased sharply to about 20 kt (Fig. 4), resulting in Ophelia undergoing a short-lived weakening period. The hurricane's intensity is estimated to have decreased to 80 kt by 1200 UTC that day due to disruption of Ophelia's inner-core convective structure, with that intensity holding steady for another 6 h. Shortly thereafter, however, the shear decreased to less than 10 kt (Fig. 4), triggering a second strengthening phase that resulted in Ophelia achieving its second and highest peak intensity of 100 kt by 1200 UTC 14 October when the hurricane was located about 500 n mi southwest of the Azores. Ophelia maintained its 100-kt major hurricane status, along with a well-defined eye in satellite imagery (Fig. 5), for another 6 h despite being located over SSTs of about 25°C — oceanic conditions generally considered to be too cold to support hurricane intensification, let alone sustain major hurricane status. As mentioned previously, however, Ophelia was embedded within an atmosphere that was colder than normal, which allowed for the generation and maintenance of strong inner-core convection despite the relatively cool SSTs.

By 0000 UTC 15 October, southwesterly vertical wind shear increased to more than 20 kt while Ophelia moved northeastward over SSTs less than 23°C, an unfavorable combination that induced a steady weakening trend. Interaction with the strong upper-level trough and jet stream flow caused the hurricane to begin losing its tropical characteristics as the vertical shear increased to more than 40 kt (Fig. 4), resulting in a comma-cloud appearance in satellite imagery — a classic signature of an extratropical cyclone. By 0000 UTC 16 October, extratropical transition was completed when the now 75-kt Ophelia merged with a strong cold front about 270 n mi southwest of Mizen Head, Ireland. The powerful post-tropical cyclone, now moving north-northeastward toward Ireland at forward speeds near 40 kt, maintained a relatively small RMW of 40–45 n mi and made landfall along the southwestern coast of Ireland near Valentia Island at around 1100 UTC 16 October, where a sharp wind shift and a pressure of 959.3 mb were observed (Fig. 6). Extratropical Ophelia continued its north-northeastward trek across western Ireland (Fig. 7) and steadily weakened, making additional landfalls near Doonshean, Cathair, and Kilcar through 1645 UTC that day. The now 50-kt extratropical low moved back over the Atlantic Ocean and made landfall near Soay, Scotland, at around 2345 UTC. Early on 17 October, extratropical Ophelia moved across northern Scotland, then emerged over the North Sea, and turned toward the east-northeast followed by a subsequent landfall near Våge, Norway, around 1730 UTC. The post-tropical cyclone moved inland and weakened over the mountainous terrain of southern Norway, and dissipated by 0000 UTC 18 October.

## 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. 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 Ophelia.

Ship reports of winds of tropical storm force associated with Ophelia are given in Table 3, and selected surface observations from land stations and data buoys are given in Table 4. Some of the 10-minute observations that had an open-ocean exposure during Ophelia's extratropical phase on 16 October were converted to an equivalent 1-minute wind speed (Harper et al. 2010), and were then reduced to a standard 10-meter wind using appropriate dropwindsonde adjustment factors for the boundary layer (Franklin et al. 2000). Those converted wind speed values were plotted in Fig. 2 during the period 1000–1700 UTC 16 October.

### *Winds and Pressure*

Ophelia's estimated peak intensity of 100 kt as a tropical cyclone is based on consensus satellite intensity estimates of T5.5/102 kt from TAFB and SAB. Although ADT intensity estimates were higher at 110 kt, GFS model soundings (not shown) indicated that both the boundary layer and troposphere were becoming increasingly stable at that time due to the cold water beneath the cyclone, which likely inhibited the normal downward mixing of higher level winds. The estimated minimum central pressure of 959 mb is based on the Knaff-Zehr-Courtney (KZC) pressure-wind relationship.

Tropical-storm-force wind gusts occurred across all of the Azores, mainly over higher elevations.

During Ophelia's status as an extratropical cyclone, the estimated minimum central pressure of 957 mb on 16 October at 0600 UTC, and also the landfall time of 1100 UTC, is based on an observed pressure of 959.3 mb at Valentia Island Observatory at 1059 UTC, which was accompanied by 1-minute wind speeds of 20–25 kt.

As extratropical cyclone Ophelia passed over Ireland on 16 October, the Fastnet Lighthouse anemometer at an elevation of 656 ft ASL recorded a 10-minute average wind speed of 78 kt and a gust to 103 kt at 1030 UTC. Roche's Point Lighthouse measured a 10-minute average wind of 60 kt and a gust to 84 kt at 1100 UTC, and just 3 h later at 1500 UTC the *Kinsale Energy* gas platform recorded a 10-minute average wind of 60 kt with a gust to 76 kt. There were also widespread reports of hurricane-force wind gusts across much of Ireland and the far western portions of the United Kingdom.

## Storm Surge and Waves

Although no values were available, significant storm surge and wave action was reported along the southern and southwestern coastal areas of Ireland. Also, the *Kinsale Energy* natural gas platform, located offshore of the southern coast of Ireland in the Celtic Sea, reported a record individual wave height of at least 85 ft (26.1 m). The previous record at the platform had been 82 ft (25 m) set in 2014. In addition, the *Irish Department of Transport and Marine Institute's* M5 weather buoy, located southeast of Ireland in the Celtic Sea recorded an individual wave height of approximately 59 ft (18 m), along with a significant wave height of at least 42 ft (12.97 m) before it broke free of its moorings and set adrift.

## Rainfall

Post-tropical Cyclone Ophelia's rapid forward speed of near 30 kt, along with its highly asymmetric rain shield being displaced mainly to the west of the cyclone's track, resulted in the most significant rain remaining over the Atlantic Ocean, with generally less than 2 inches (50 mm) of rainfall occurring across Ireland and the United Kingdom (Table 4; Fig. 7).

## CASUALTY AND DAMAGE STATISTICS

There were no reports of casualties<sup>2</sup> associated with Ophelia while it was a tropical cyclone.

However, three deaths occurred in Ireland during Ophelia's extratropical phase. Media reports indicate that a woman in her 70s was killed after a tree fell on her car in Waterford in the southeastern portion of the country, a man in his 30s was killed during a chainsaw accident while clearing a fallen tree in Tipperary County, and another man died in Louth near Dublin after his car was struck by a tree.

As the center of Ophelia passed southeast of the Azores on 14 October, tropical-storm-force wind gusts downed a few trees on the islands of São Miguel, Ponta Delgada, Povoação. The Azores Regional Service of Civil Protection reported that some minor flooding occurred.

Extratropical Ophelia was the worst storm to affect Ireland in 50 years. More than 360,000 customers in Ireland, plus approximately 50,000 households in Northern Ireland, lost electricity due to strong winds blowing down utility poles and trees falling on above-ground powerlines. Downed trees also forced officials to close many roads, including major highways, across most of Ireland. Numerous homes and other structures were damaged across much of Ireland and portions of the United Kingdom due to Ophelia's winds. Media reports indicate that the cyclone caused an estimated USD\$7 million in insured losses in Ireland, while insurance claims are

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<sup>2</sup> Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered "indirect" deaths.

estimated to be USD\$6.6 million to USD\$13 million due to damages in Northern Ireland, Wales, and Scotland.

## FORECAST AND WARNING CRITIQUE

Ophelia's genesis was well forecast, especially given the cyclone's extratropical origins (Kimberlain 2014), resulting in lead times nearly twice the typical lead times for similar systems of non-tropical origin. The 120-h potential for the formation of a subtropical or tropical cyclone was first introduced in the Tropical Weather Outlook with a low probability (<40%) 90 h prior to genesis (Table 2). The 5-day genesis probabilities were subsequently increased into the medium (40%–60%) and high (>60%) categories 66 h and 42 h, respectively, before formation occurred. For the 48-h genesis outlook, the system was introduced with a low probability (<40%) 72 h prior to formation. The 2-day genesis probabilities were raised into the medium and high categories 48 h and 42 h, respectively, before Ophelia developed. The global models, especially the NOAA Global Forecast System (GFS) and European Centre for Medium-Range Weather Forecasts (ECMWF) models, provided excellent guidance on the genesis of Ophelia about 72–96 h before genesis occurred. However, Ophelia was forecast to weaken significantly or even dissipate within a day or two after the system had formed, when the opposite actually occurred.

A verification of NHC official track forecasts for Ophelia (excluding the post-tropical/extratropical stage) is given in Table 5a. Official forecast track errors (OFCL) were significantly lower than the mean official errors for the previous 5-yr period from 12 h to 96 h, with errors ranging from 20% to 63%, respectively, better than average. At 120 h, however, the OFCL error was almost 20% greater than the previous 5-yr average. In contrast, OCD5 track errors ranged from 15% to 34% greater than average between 36 h to 120 h, which indicates that Ophelia was more difficult than average to forecast. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. OFCL track forecasts outperformed the overwhelming majority of the available model guidance at 12–96 h, with the exception of the NOAA Hurricane Corrected Consensus Approach (HCCA) and Florida State Superensemble (FSSE) models. At 120 h, OFCL forecasts were bested by all of the track forecast guidance, with the exception of the Trajectory and Beta (TAB) models. OFCL track forecasts correctly indicated that the western half of Ireland would likely experience a landfall by Ophelia and were characterized by a relatively small cross-track spread of less than 100 n mi (Fig. 8).

A verification of NHC official intensity forecasts for Ophelia (excluding the post-tropical/extratropical stage) is given in Table 6a. Official forecast intensity errors were comparable to the mean official errors for the previous 5-yr period through 48 h. However, from 72–120 h, OFCL errors were significantly greater than average, ranging from about 35% to near 100% worse, respectively. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. NHC OFCL intensity forecast errors were comparable to the available intensity guidance at 12 and 24 h, but were worse than most of the models after that. The best performing intensity guidance were the Decay-SHIPS (DSHP), Hurricanes in a Multiscale Ocean-Coupled Non-Hydrostatic (HMNI), and FSSE models. The larger-than-average OFCL intensity errors were due to a failure to forecast Ophelia becoming a major hurricane. During the time that Ophelia reached 100 kt, the preceding 4-days of OFCL intensity forecasts

indicated a weakening trend and averaged about 25 kt lower than the hurricane's actual peak intensity (Fig. 9).

No tropical cyclone watches or warnings were issued in association with Ophelia for land areas. However, various public advisories and warnings were issued by the Irish National Meteorological Service (Met Éireann) and the United Kingdom Meteorological Office (UKMET) to highlight the high wind and storm surge threats for Ireland and portions of the United Kingdom during Ophelia's powerful post-tropical/extratropical phase.

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## ACKNOWLEDGMENTS

Special thanks to Hurricane Specialist John Cangialosi for preparing the Hurricane “best track” map (Fig. 1). Data in Table 4 were compiled partly from Post-Tropical Cyclone Reports provided by the meteorological departments at Met Éireann (Irish National Meteorological Service) and the UKMET (United Kingdom Meteorological Office).



Table 1. Best track for Hurricane Ophelia, 9–15 October 2017.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
06 / 1200	31.8	39.5	1013	20	low
06 / 1800	32.3	38.6	1012	20	"
07 / 0000	32.9	37.3	1011	25	"
07 / 0600	32.7	38.5	1010	30	"
07 / 1200	32.3	39.5	1010	30	"
07 / 1800	31.5	39.5	1010	30	"
08 / 0000	31.3	39.5	1010	30	"
08 / 0600	31.0	39.6	1010	35	"
08 / 1200	30.6	39.7	1009	35	"
08 / 1800	30.4	40.1	1009	35	"
09 / 0000	30.5	40.1	1008	35	"
09 / 0600	30.9	40.0	1008	35	tropical storm
09 / 1200	31.3	40.0	1008	35	"
09 / 1800	31.7	39.6	1005	40	"
10 / 0000	32.0	39.1	1005	40	"
10 / 0600	31.9	38.8	1003	45	"
10 / 1200	31.6	38.5	1002	45	"
10 / 1800	31.3	38.2	1002	45	"
11 / 0000	30.9	37.8	1000	50	"
11 / 0600	30.4	37.2	998	55	"
11 / 1200	30.0	36.7	994	60	"
11 / 1800	29.8	36.2	991	65	hurricane
12 / 0000	29.9	35.8	986	70	"
12 / 0600	30.2	35.7	982	75	"
12 / 1200	30.4	35.7	975	80	"
12 / 1800	30.5	35.6	971	85	"
13 / 0000	30.5	35.1	967	90	"
13 / 0600	30.9	34.4	966	90	"
13 / 1200	31.4	33.4	974	80	"
13 / 1800	32.0	32.5	973	80	"
14 / 0000	32.6	31.5	970	85	"
14 / 0600	33.4	29.7	963	95	"
14 / 1200	34.2	27.7	959	100	"
14 / 1800	35.3	25.2	959	100	"
15 / 0000	36.4	22.6	959	95	"
15 / 0600	37.9	19.8	959	90	"
15 / 1200	39.9	17.0	959	85	"





15 / 1800	43.1	14.3	959	80	"
16 / 0000	47.6	13.4	958	75	extratropical
16 / 0600	50.0	12.1	957	70	"
16 / 1200	52.3	10.0	959	65	"
16 / 1800	55.3	8.3	969	60	"
17 / 0000	57.3	6.1	977	50	"
17 / 0600	58.7	2.9	987	45	"
17 / 1200	59.3	1.5 E	994	40	"
17 / 1800	60.1	5.3 E	997	40	"
18 / 0000					dissipated over Norway
14 / 1200	34.2	27.7	959	100	minimum pressure and maximum intensity
16 / 0000	47.6	13.4	958	75	maximum intensity as an extratropical low
16 / 0600	50.0	12.1	957	70	minimum pressure as an extratropical low
16 / 1100	51.9	10.4	957	65	extratropical landfall on Valentia Island, Ireland

Table 2. 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%)	72	90
Medium (40%-60%)	48	66
High (>60%)	42	42

Table 3. Selected ship reports with winds of at least 34 kt for Hurricane Ophelia, 9–15 October 2017. Report during extratropical phase indicated by an asterisk (\*).

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
14 / 0700	2IYG9	35.6	37.0	360 / 40	1016.2
14 / 1300	VRMW7	33.9	31.5	350 / 37	1016.0
15 / 0600	VRHE3	36.9	12.5	270 / 35	1015.0
16 / 0200*	ZCDT2	49.3	3.9	180 / 40	1011.2
16 / 0600*	ZCDT2	48.4	5.4	200 / 42	1006.7

Table 4. Selected surface observations for Hurricane Ophelia on 12–15 October 2017 and for Post-Tropical/Extratropical Ophelia on 16–17 October 2017.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
<b>Azores</b>									
<b>ICAO Sites</b>									
Flores Airport (LPFL) (39.46N 31.13W) (Elev. 105 ft / 32 m ASL)	14/1130	1012.9	14/1300	20 (10 min)	35				
João Paulo II Airport (LPPD)(37.74N 25.70W) (Elev. 259 ft / 79 m ASL)	14/2000	1007.1	14/2030	26 (10 min)	38				
Santa Maria Airport (LPAZ)(36.97N 25.17W) (Elev. 308 ft / 94 m ASL)	14/2030	1005.1	14/2230	29 (10 min)	37				
<b>Ireland</b>									
<b>ICAO Sites</b>									
Cork Airport (EICK) (52.84N 8.49W) (Elev. 502 ft / 153 m ASL)	16/1100	981.0	16/1200	43 (10 min)	68				
Dublin Airport (EIDW) (53.42N 6.27W) (Elev. 242 ft / 74 m ASL)	16/1430	989.0	16/1330	36 (10 min)	56				
Casemont Airport (EIMF) (53.31N 6.44W) (Elev. 319 ft / 97 m ASL)	16/1430	989.0	16/1430	41 (10 min)	63				
Ireland W. Arpt-Knock (EIKN) (53.91N 8.82W) (Elev. 665 ft / 203 m ASL)	16/1430	972.0	16/1400	32 (10 min)	50				
Shannon Airport (EINN) (52.70N 8.92W) (Elev. 46 ft / 14 m ASL)	16/1230	973.0	16/1130	47 (10 min)	66				
Waterford Airport (EIWF) (52.19N 7.09W) (Elev. 119 ft / 36 m ASL)	16/1330	991.0	16/1330	52 (10 min)	74				
<b>Public/Other</b>									
Athenry (Galway Co.)			16/1300	31 (10 min)	51				
Ballyhaise (Cavan Co.)			16/1400	23 (10 min)	50				



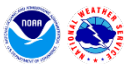
Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
Belmullet (Mayo Co.)			16/0800	26 (10 min)	47				
Casement (Dublin Co.)			16/1300	39 (10 min)	63				
Clairemorris (Mayo Co.)			16/1300	26 (10 min)	44				
Fastnet Lighthouse (51.38N 9.60W) (Elev. 656 ft / 200 m ASL)			16/1030 <sup>f</sup>	78 (10 min)	103				
Finner (Donegal Co.)			16/1700	35 (10 min)	54				
Grange-Dunsany (Meath Co.)			16/1400	28 (10 min)	57				
Gurteen (Offaly Co.)			16/1300	35 (10 min)	55				
Johnstown Castle (Wexford Co.)			16/1300	35 (10 min)	62				
Mace Head (Galway Co.)			16/0700	37 (10 min)	51				
Malin Head (Donegal Co.)			16/2000	39 (10 min)	57				
Moore Park-Fermoy (Cork Co.)			16/1200	36 (10 min)	62				
Mount Dillon (Roscommon Co.)			16/1400	31 (10 min)	50				
Mullingar (Westmeath Co.)			16/1400	26 (10 min)	49				
Newport (Mayo Co.)			16/0600	22 (10 min)	43				
Oak Park (Carlow Co.)			16/1300	32 (10 min)	60				
Roche's Point Lighthouse (Cork Co.) (51.77N 8.25W) (Elev. 136 ft / 41.4 m ASL)			16/1100	60 (10 min)	84				
Sherkin Island (Cork Co.)			16/0930 <sup>g</sup>	47 (10 min)	74				
Valentia Observatory (Kerry Co.) (51.94N 10.24W) (Elev. 82 ft / 25 m ASL)	16/1100	959.0	16/1000	31 (10 min)	53				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
<b>Offshore Buoys &amp; Platforms</b>									
Buoy M2 (62091) (53.47N 5.42W)			16/1600	40 (10 min/4.5 m)	60				
Buoy M3 (62092) (51.13N 10.33W)			16/1500	41 (10 min/4.5 m)	56				
Buoy M4 (62093) (55.00N 10.00W)			16/1000	35 (10 min/4.5 m)	49				
Buoy M5 (62094) (51.41N 6.42W)			16/1300	41 (10 min/4.5 m)	59				
Buoy M6 (62095) (53.04N 15.53W)			16/1500	33 (10 min/4.5 m)	47				
Kinsale Gas Platform (offshore of Old Head of Kinsale, Cork Co.)			16/1500	60 (10 min)	76				
<b>Isle of Man</b>									
<b>ICAO Sites</b>									
Ronaldsway Airport (EGNS) (54.08N 4.62W) (Elev. 52 ft / 16 m ASL)	16/1620	996.0	16/1520	50 (10 min)	68				
<b>Norway</b>									
<b>ICAO Sites</b>									
Haugesund Airport (ENHD) (59.34N 5.21E) (Elev. 87 ft / 27 m ASL)	17/1720	996.9 <sup>h</sup>	17/1720	21 (10 min)	33				
Oseberg A Oil Platform – Heliport (ENOA) (60.49N 2.83E)	17/1250	996.9 <sup>h</sup>	17/1650	48 (10 min)					
<b>United Kingdom</b>									
<b>England</b>									
<b>ICAO Sites</b>									
Birmingham Airport (EGBB) (52.45N 1.75W) (Elev. 341 ft / 104 m ASL)	16/1550	1009.0	16/1550	19 (10 min)	37				
Blackpool Airport (EGNH) (53.77N 3.03W) (Elev. 34 ft / 10 m ASL)	16/1650	1004.0	16/1950	34 (10 min)	46 <sup>h</sup>				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
Cornwall Airport (EGHQ) (50.44N 4.99W) (Elev. 390 ft / 119 m ASL)	16/0650	1006.0	16/1020	33 (10 min)	49				
Cranfield Airport (EGTC) (52.07N 0.62W) (Elev. 358 ft / 109 m ASL)	16/1620 <sup>i</sup>	1012.0	16/1450 <sup>i</sup>	25 (10 min)	37				
Doncaster Airport (EGCN) (53.48N 1.00W) (Elev. 56 ft / 17 m ASL)	16/1720	1008.0	16/2250	30 (10 min)	42				
Durham Tees Valley Airport (EGNV) (54.51N 1.43W) (Elev. 120 ft / 37 m ASL)	16/1850	1003.0	17/0450	35 (10 min)	47 <sup>h</sup>				
East Midlands Airport (EGNX) (52.83N 1.33W) (Elev. 306 ft / 93 m ASL)	16/1750	1009.0	16/1720	31 (10 min)	48				
Exeter Airport (EGTE) (50.73N 3.41W) (Elev. 102 ft / 31 m ASL)	16/0920	1010.2	16/1420	23 (10 min)	36				
Farnborough Airport (EGLF) (51.28N 0.78W) (Elev. 238 ft / 73 m ASL)	16/1320	1014.0	16/1350	21 (10 min)	36				
Humberside Airport (EGNJ) (53.57N 0.35W) (Elev. 121 ft / 37 m ASL)	16/1620	1007.0	16/1950	27 (10 min)	41				
Leeds Bradford Apt. (EGNM) (53.87N 1.77W) (Elev. 681 ft / 208 m ASL)	16/1920	1005.0	16/2050	20 (10 min)	43				
Liverpool Airport (EGGP) (53.33N 2.85W) (Elev. 81 ft / 25 m ASL)	16/1520	1004.0	16/1620	37 (10 min)	53				
Manchester Airport (EGCC) (53.35N 2.28W) (Elev. 257 ft / 78 m ASL)	16/1750	1006.0	16/1750	19 (10 min)	36				
Newcastle Airport (EGNT) (55.04N 1.69W) (Elev. 266 ft / 81 m ASL)	16/2350	1001.0	16/2350	25 (10 min)	43				
RAF Brize Norton (EGVN) (51.75N 1.58W) (Elev. 287 ft / 88 m ASL)	16/1550	1011.8	16/1650	20 (10 min)	39				
RAF Cranwell (EGYD) (53.03N 0.48W) (Elev. 217 ft / 66 m ASL)	16/1650	1009.1	16/1750	26 (10 min)	36				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
RAF Fairford (EGVA) (51.68N 1.79W) (Elev. 285 ft / 87 m ASL)	16/1056	1011.6	16/1438	24 (10 min)	36				
RAF Leeming (EGXE) (54.29N 1.54W) (Elev. 132 ft / 40 m ASL)	16/2150	1004.1	16/2150	29 (10 min)	39				
RAF Leconfield (EGXV) (53.88N 0.44W) (Elev. 23 ft / 7 m ASL)	16/1650	1006.1	17/0050	27 (10 min)	39				
RAF Linton-on-Ouse (EGXU) (54.05N 1.25W) (Elev. 53 ft / 16 m ASL)	16/1750	1005.1	16/2050	32 (10 min)	46				
RAF Marham (EGYM) (52.65N 0.55W) (Elev. 77 ft / 24 m ASL)	16/1650	1011.8	16/1550	23 (10 min)	34				
RAF Mildenhall (EGUN) (52.37N 0.48W) (Elev. 32 ft / 10 m ASL)	16/1356	1011.8	16/1542	23 (10 min)	35				
RAF Scampton (EGXP) (53.30N 0.55W) (Elev. 202 ft / 62 m ASL)	16/1850	1008.1	17/0050	26 (10 min)	37				
RAF Shawbury (EGOS) (52.80N 2.67W) (Elev. 248 ft / 76 m ASL)	16/1350	1006.0	16/1650	32 (10 min)	48				
RAF Spadeadam (EGOM) (55.03N 2.60W) (Elev. 1066 ft / 325 m ASL)	16/2250	999.0	17/0650	32 (10 min)	47 <sup>h</sup>				
RAF Swinderby (EGXS) (53.15N 0.67W) (Elev. 62 ft / 19 m ASL)	16/1650	1008.1	17/0950	25 (10 min)	35				
RAF Topcliffe (EGXZ) (54.21N 1.38W) (Elev. 92 ft / 28 m ASL)	16/1950	1005.1	16/2250	26 (10 min)	38				
RAF Waddington (EGXW) (53.17N 0.53W) (Elev. 230 ft / 70 m ASL)	16/1850	1009.1	16/1750	27 (10 min)	36				
RAF Wittering (EGXT) (52.61N 0.48W) (Elev. 273 ft / 83 m ASL)	16/1650	1010.2	17/1550	25 (10 min)	40				
St. Mary's Airport (EGHE) (49.91N 6.30W) (Elev. 115 ft / 35 m ASL)			16/1050	47 (10 min)	61				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
Warton Aerodrome (EGNO) (53.76N 2.88W) (Elev. 55 ft / 17 m ASL)	16/1750	1004.0	16/1750	27 (10 min)	40				
<b>Public/Other</b>									
High Bradfield (53.43N 1.60W) (Elev. 1296 ft / 395 m ASL)			16/----		67				
St. Bees Head (54.49N 3.59W) (Elev. 407 ft / 124 m ASL)			16/----		65				
<b>Northern Ireland</b>									
<b>ICAO Sites</b>									
Belfast Airport (EGAA) (54.67N 6.22W) (Elev. 268 ft / 82 m ASL)	16/1650	987.0	16/1450	38 (10 min)	52				
<b>Public/Other</b>									
Orlock Head (54.67N 5.58W) (Elev. 112 ft / 34 m ASL)			16/----		62				
<b>Scotland</b>									
<b>ICAO Sites</b>									
Aberdeen Airport (EGPD) (58.96N 2.90W) (Elev. 215 ft / 66 m ASL)	17/0420	990.0 <sup>h</sup>	17/0420	35 (10 min)	36				
Boulmer Airport (EGQM) (55.42N 1.60W) (Elev. 75 ft / 23 m ASL)	17/0250	999.0 <sup>h</sup>	17/0350	32 (10 min)	48 <sup>h</sup>				
Edinburgh Airport (EGPH) (55.95N 3.37W) (Elev. 136 ft / 41 m ASL)	17/0120	993.9 <sup>h</sup>	17/0350	33 (10 min)	47				
Glasgow Airport (EGPF) (55.87N 4.43W) (Elev. 26 ft / 8 m ASL)	16/2150	991.9	17/1020	37 (10 min)	51 <sup>h</sup>				
Glasgow Prestwick Airport (EGPK) (55.51N 4.59W) (Elev. 65 ft / 20 m ASL)	16/2020	991.9	17/0350	30 (10 min)	42 <sup>h</sup>				
Inverness Airport (EGPE) (57.54N 4.05W) (Elev. 31 ft / 9 m ASL)	17/0350	987.1							







Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
Tulloch Bridge (56.87N 4.71W) (Elev. 777 ft / 238 m ASL)									1.32
Tyndrum (56.44N 4.71W) (Elev. 751 ft / 229 m ASL)									1.44
<b>Wales</b>									
<b>ICAO Sites</b>									
Caernarfon Airport (EGCK) (53.1N 4.34W) (Elev. 14 ft / 4 m ASL)	16/1620	1001.0	16/1550	44 (10 min)	60 <sup>h</sup>				
Cardiff Airport (EGFF) (51.40N 3.34W) (Elev. 220 ft / 67 m ASL)	16/1550	1011.0	16/1350	22 (10 min)	35				
Hawarden Airport (EGNR) (53.18N 2.98W) (Elev. 45 ft / 14 m ASL)	16/1750	1005.0	16/1520	36 (10 min)	54				
RAF Pembrey Sands (EGOP) (51.71N 4.37W) (Elev. 22 ft / 7 m ASL)	16/0750	1006.0	16/1350	49 (10 min)	65				
RAF Valley Airport (EGOV) (53.28N 4.54W) (Elev. 36 ft / 11 m ASL)	16/1650	999.0	16/1450	51 (10 min)	70				
<b>Public/Other</b>									
Aberdaron (52.79N 4.74W) (Elev. 312 ft / 95 m ASL)			16/----		78				
Aberporth (52.14N 4.57W) (Elev. 436 ft / 133 m ASL)			16/----		64				
Capel Curig (52.14N 4.57W) (Elev. 708 ft / 216 m ASL)			16/----		78				
Lake Vyrnwy (52.76N 3.46W) (Elev. 1181 ft / 360 m ASL)			16/----		61				
Milford Haven (51.71N 5.04W) (Elev. 33 ft / 10 m ASL)			16/----		65				
Mona-Anglesey (53.26N 4.38W) (Elev. 197 ft / 60 m ASL)			16/----		67				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Estimated Inundation (ft) <sup>e</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)				
Mumbles Head (51.57N 3.98W) (Elev. 105 ft / 32 m ASL)			16/----		69				
Pembrey Sands (51.71N 4.37W) (Elev. 10 ft / 3 m ASL)			16/----		65				

<sup>a</sup> Date/time is for wind gust.

<sup>b</sup> Sustained wind averaging period is 10 minutes, unless otherwise noted.

<sup>c</sup> Storm surge is water height above normal astronomical tide level.

<sup>d</sup> For most locations, storm tide is water height above the North American Vertical Datum of 1988 (NAVD88). Storm tide is water height above Mean Lower Low Water (MLLW) for NOS stations in Puerto Rico, the U.S. Virgin Islands, and Barbados.

<sup>e</sup> Estimated inundation is the maximum height of water above ground. For some USGS storm tide pressure sensors, inundation is estimated by subtracting the elevation of the sensor from the recorded storm tide. For other USGS storm tide sensors and USGS high-water marks, inundation is estimated by subtracting the elevation of the land derived from a Digital Elevation Model (DEM) from the recorded and measured storm tide. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.

<sup>f</sup> Time estimated.

<sup>g</sup> Last report 0930 UTC 16 October 2017.

<sup>h</sup> Last of multiple occurrences.

<sup>i</sup> Missing data 16/1621 UTC to 17/0619 UTC October 2017..



Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Ophelia. 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	<b>19.8</b>	<b>28.9</b>	<b>35.7</b>	<b>44.7</b>	<b>52.8</b>	<b>57.1</b>	247.9
OCD5	44.6	115.0	193.7	280.6	458.4	586.4	613.9
Forecasts	25	23	21	19	15	11	7
OFCL (2012-16)	24.9	39.6	54.0	71.3	105.8	155.4	208.9
OCD5 (2012-16)	47.3	103.9	167.8	230.3	343.1	442.6	531.0

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Ophelia. 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	18.1	29.1	33.2	37.8	52.1	49.5	273.3
OCD5	42.6	108.6	172.1	271.7	474.0	654.6	798.0
GFSI	21.0	35.1	41.5	52.3	70.5	100.8	329.5
EMXI	<b>15.3</b>	<b>25.1</b>	34.9	39.1	<b>49.1</b>	60.6	<b>140.8</b>
EGRI	25.8	36.1	39.2	48.4	75.5	109.4	<b>271.4</b>
CMCI	23.5	43.5	52.6	72.9	115.0	145.6	<b>220.6</b>
NVGI	27.0	48.8	64.9	85.7	135.8	230.3	472.1
AEMI	22.6	37.3	45.9	52.8	72.7	105.5	<b>220.5</b>
HWFI	20.5	33.2	42.6	55.2	102.5	145.5	<b>205.0</b>
HMNI	23.7	41.7	57.6	69.6	105.4	171.6	<b>169.2</b>
CTCI	22.2	35.6	52.9	66.8	76.6	84.1	<b>184.3</b>
HCCA	<b>15.7</b>	<b>24.8</b>	<b>29.7</b>	<b>33.0</b>	<b>47.7</b>	<b>35.2</b>	<b>144.4</b>
FSSE	<b>17.4</b>	<b>26.2</b>	<b>30.1</b>	<b>34.0</b>	<b>47.7</b>	<b>29.4</b>	<b>164.6</b>
TVCA	19.5	29.4	37.0	43.9	<b>51.2</b>	66.9	<b>208.9</b>
TVCX	18.5	<b>27.9</b>	34.5	40.3	<b>47.7</b>	58.6	<b>195.9</b>
GFEX	18.1	<b>27.0</b>	33.4	<b>37.6</b>	<b>43.8</b>	57.3	<b>228.2</b>
TCON	21.5	32.6	37.2	44.5	62.2	88.4	<b>253.4</b>
TABD	20.9	39.8	59.5	71.9	89.9	118.3	332.6
TABM	23.2	44.5	58.9	65.5	71.6	100.7	351.1
TABS	41.1	80.6	95.5	96.2	78.8	156.5	370.1
Forecasts	20	18	16	15	11	7	3



Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Ophelia. 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	6.0	<b>7.8</b>	10.5	<b>11.6</b>	18.0	21.8	28.6
OCD5	7.6	12.8	19.3	23.9	31.4	30.8	39.7
Forecasts	25	23	21	19	15	11	7
OFCL (2012-16)	5.5	8.2	10.5	12.0	13.4	14.0	14.5
OCD5 (2012-16)	7.1	10.5	13.0	15.1	17.4	18.2	20.6

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Ophelia. 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	6.0	8.1	12.2	13.9	16.8	22.1	16.7
OCD5	7.6	13.6	21.8	26.6	31.8	34.9	32.3
DSHP	<b>5.8</b>	8.7	<b>11.6</b>	<b>13.2</b>	<b>14.1</b>	<b>15.7</b>	<b>7.0</b>
LGEM	<b>5.8</b>	8.6	<b>12.1</b>	14.1	18.2	24.0	19.7
HWFI	7.4	8.8	<b>12.1</b>	16.4	18.3	<b>21.0</b>	<b>3.3</b>
CTCI	9.8	12.6	15.6	<b>13.4</b>	<b>15.4</b>	<b>17.3</b>	<b>10.7</b>
HMNI	6.2	<b>7.1</b>	<b>7.3</b>	<b>7.0</b>	<b>9.5</b>	<b>20.7</b>	19.7
ICON	6.2	8.4	<b>11.6</b>	14.2	<b>16.6</b>	<b>19.9</b>	<b>7.3</b>
IVCN	6.9	9.2	<b>11.9</b>	<b>13.6</b>	<b>16.3</b>	<b>19.0</b>	<b>8.0</b>
HCCA	6.8	8.6	<b>11.1</b>	<b>13.7</b>	<b>16.5</b>	<b>20.0</b>	<b>8.3</b>
FSSE	6.1	<b>7.7</b>	<b>8.4</b>	<b>9.1</b>	<b>9.8</b>	<b>15.4</b>	<b>9.0</b>
GFSI	7.6	8.1	<b>6.9</b>	<b>10.7</b>	<b>14.0</b>	<b>16.7</b>	<b>7.3</b>
EMXI	10.3	13.7	15.7	21.4	25.0	25.9	<b>8.7</b>
EGRI	8.9	11.9	<b>11.5</b>	14.1	<b>15.3</b>	<b>18.4</b>	<b>7.7</b>
CMCI	9.6	13.2	13.2	18.3	22.3	27.0	21.3
NVGI	9.5	13.0	<b>11.9</b>	15.4	18.3	<b>22.0</b>	<b>11.0</b>
AEMI	9.9	14.9	17.1	21.9	25.5	29.3	22.7
Forecasts	20	18	16	14	11	7	3

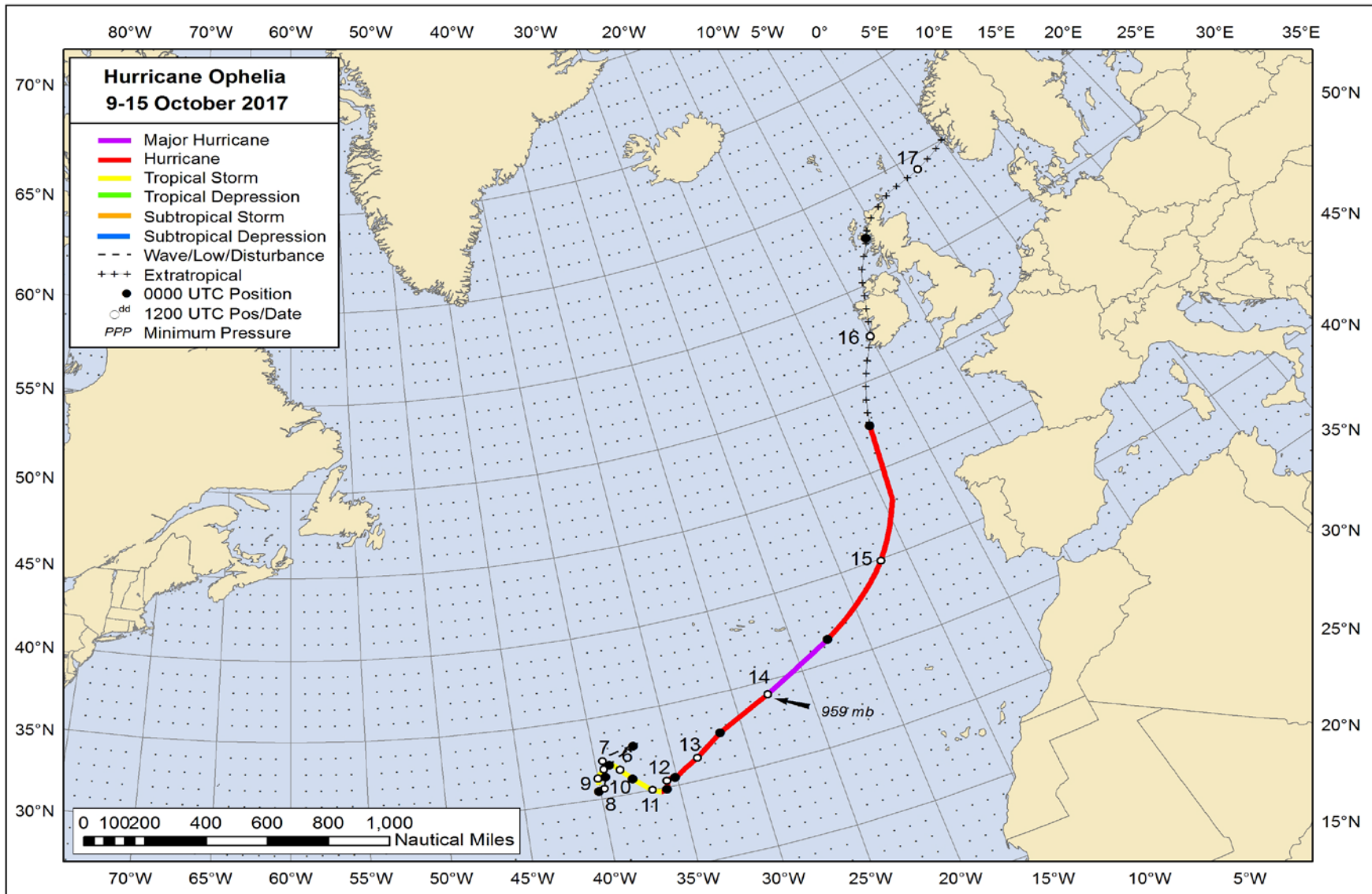


Figure 1. Best track positions for Hurricane Ophelia, 9–15 October 2017. The track during the extratropical stage on 16–17 October is partially based on analyses from the NOAA Ocean Prediction Center, Met Éireann (Irish National Meteorological Service), and the UKMET (United Kingdom Meteorological Office).



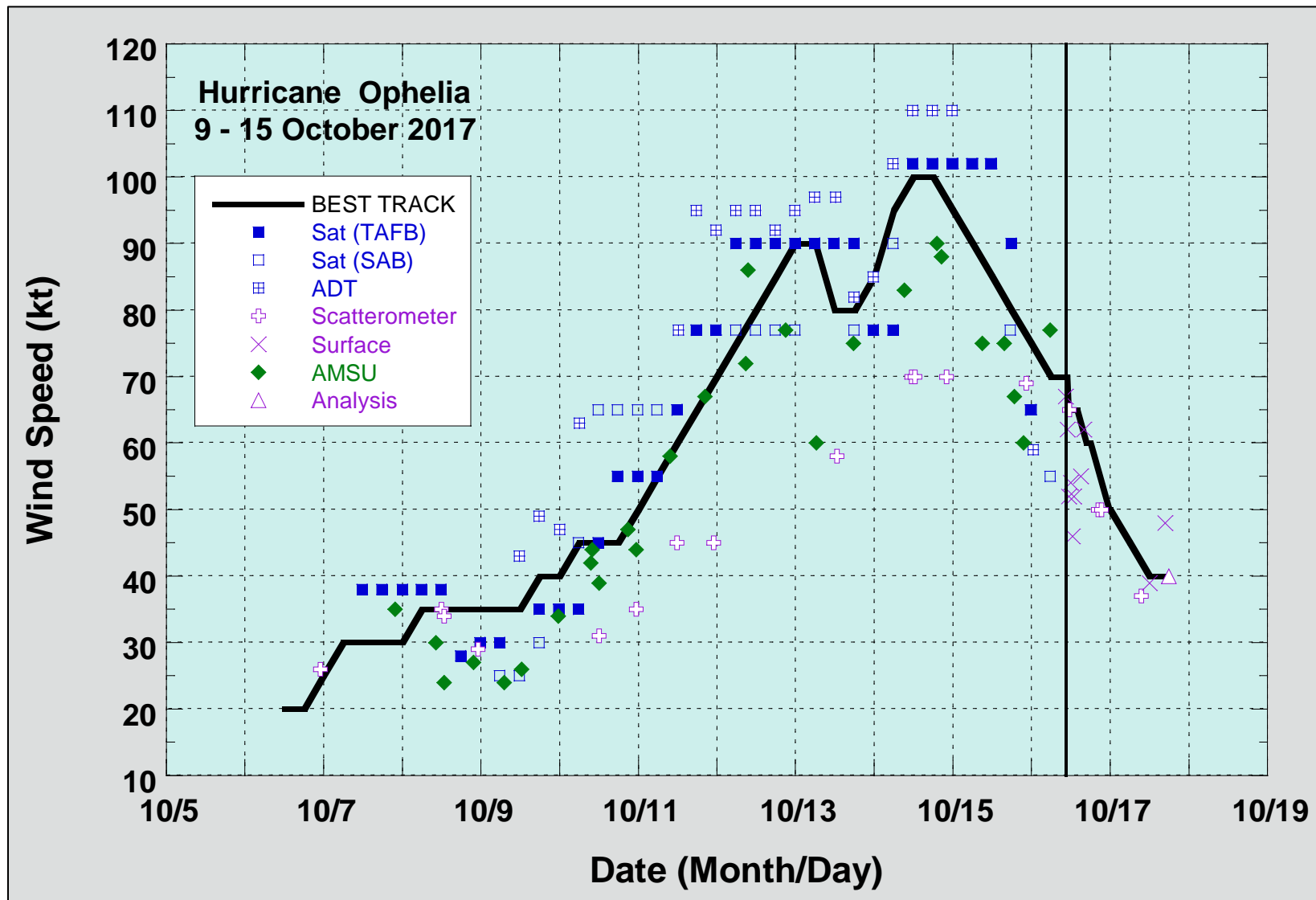


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Ophelia, 9–15 October 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC. Solid vertical line corresponds to Ophelia’s post-tropical landfall as an extratropical cyclone on Ireland.

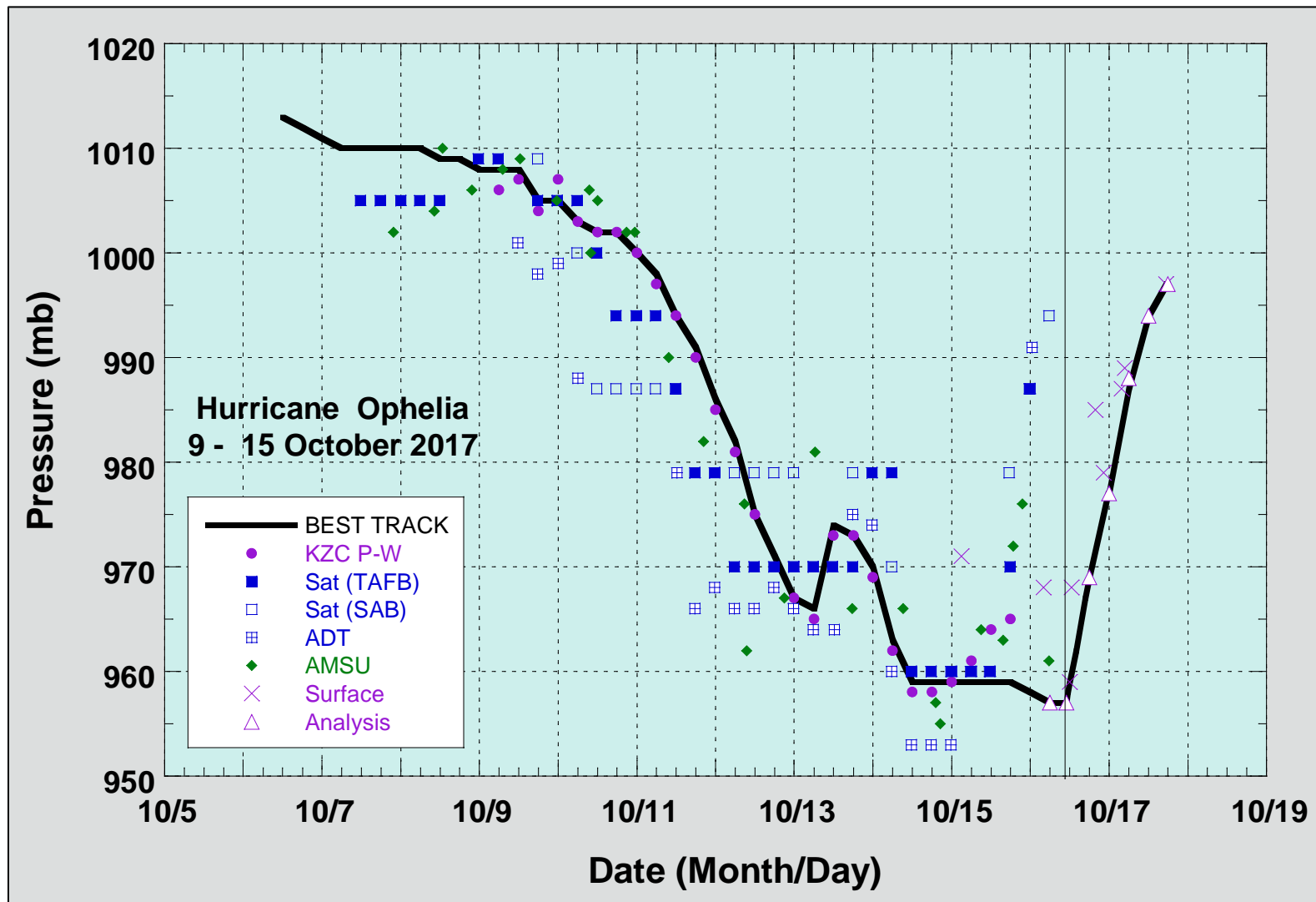


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Ophelia, 9–15 October 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological 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. Solid vertical line corresponds to Ophelia’s post-tropical landfall as an extratropical cyclone on Ireland.

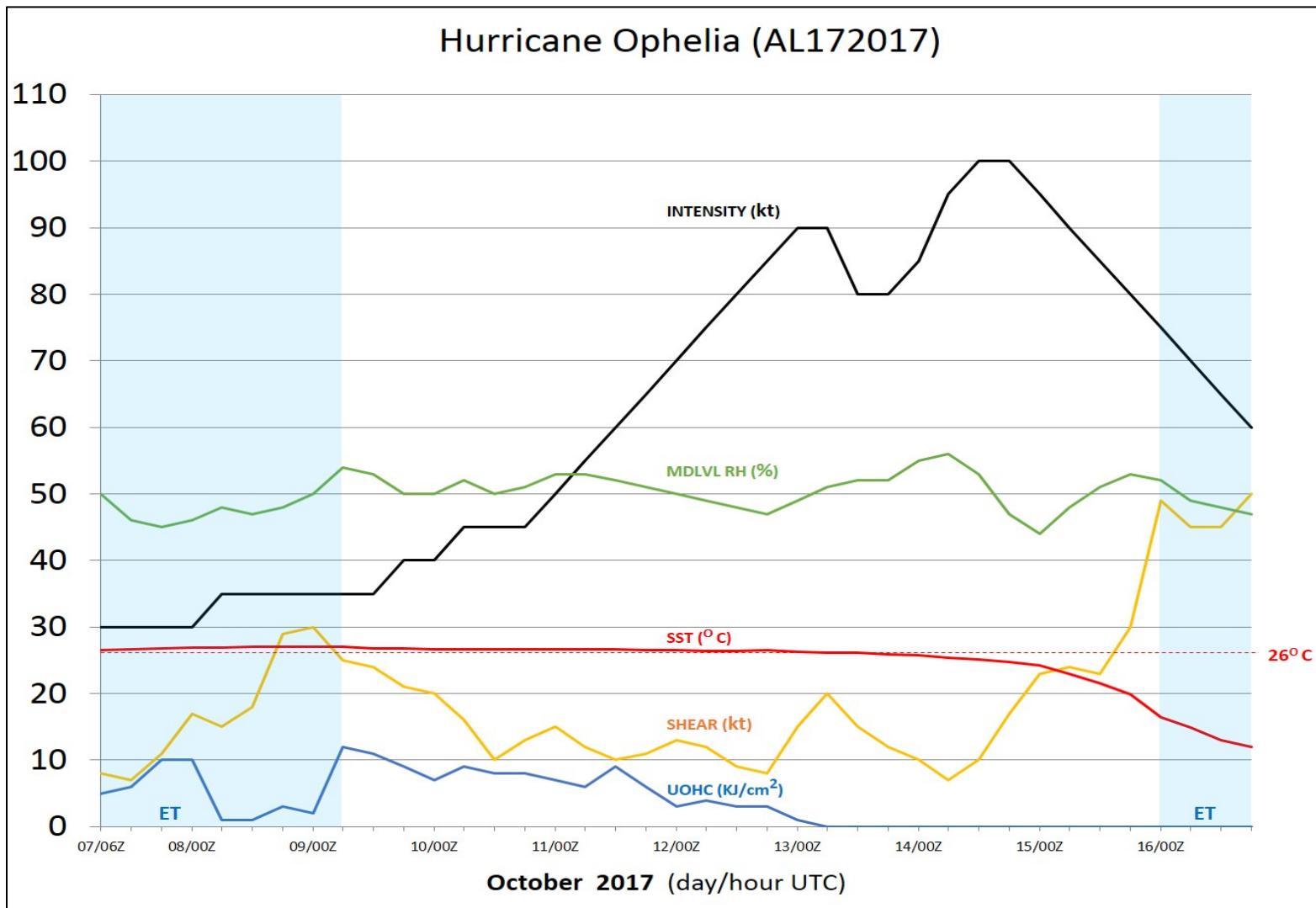


Figure 4. Graph of Hurricane Ophelia’s intensity versus GFS-based SHIPS model analyzed environmental parameters: 850–200-mb vertical wind shear (SHEAR), sea-surface temperature (SST), upper-ocean heat content (UOHC), and 700–500-mb average relative humidity (MDLVL RH). Time period covered is from 0600 UTC 7 October to 1800 UTC 16 October 2017, which includes the extratropical phases (ET) before and after Ophelia’s lifetime as a tropical cyclone (blue shading).

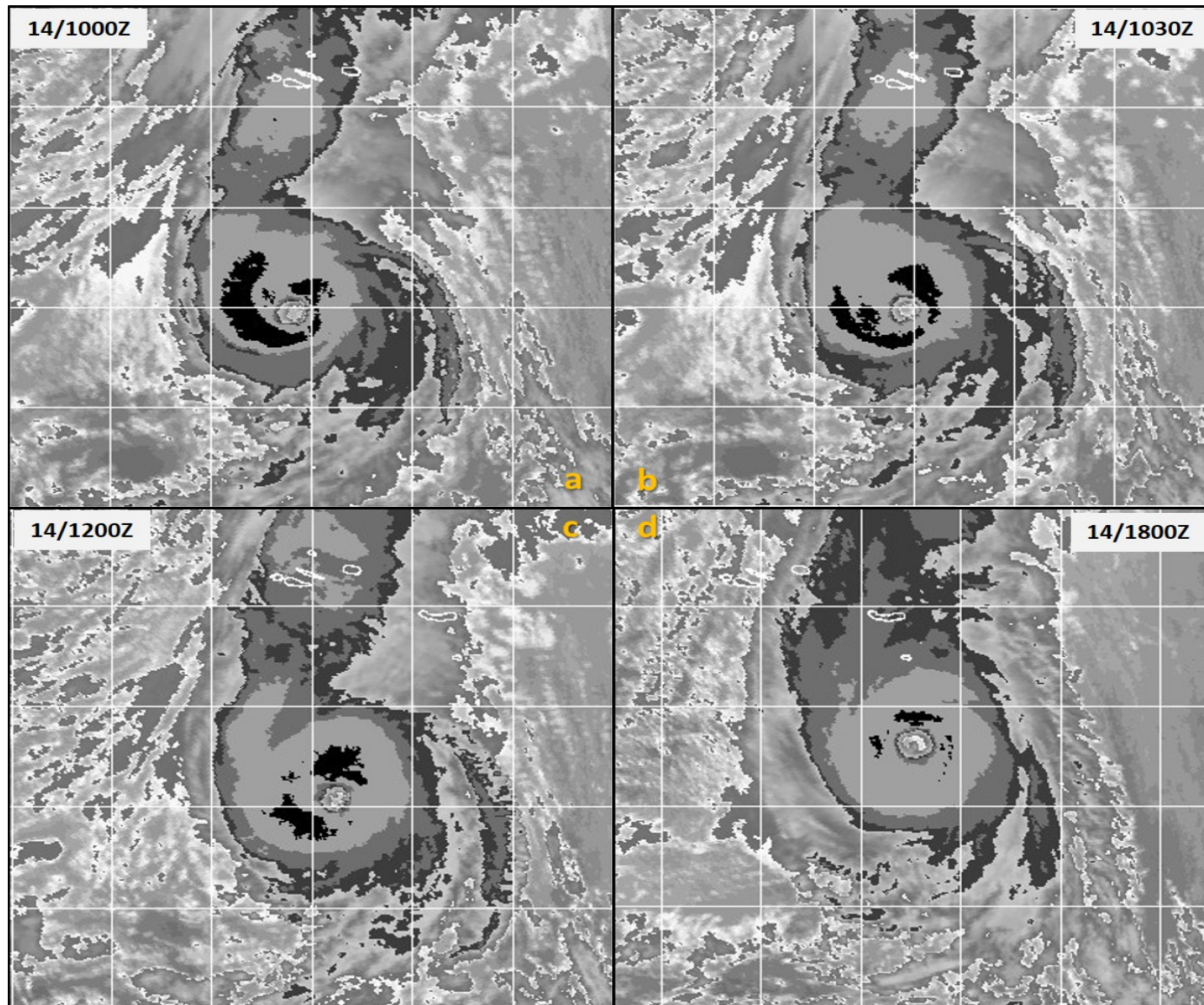


Figure 5. EUMETSAT MSG-3 infrared satellite images with BD-enhancement curve depicting Ophelia's well-defined eye when the tropical cyclone was a 100-kt major hurricane passing south of the Azores on 14 October 2017: (a) 1000 UTC, (b) 1030 UTC, (c) 1200 UTC, and (d) 1800 UTC. Images courtesy of the U.S. Naval Research Laboratory (NRL), Monterey, CA.

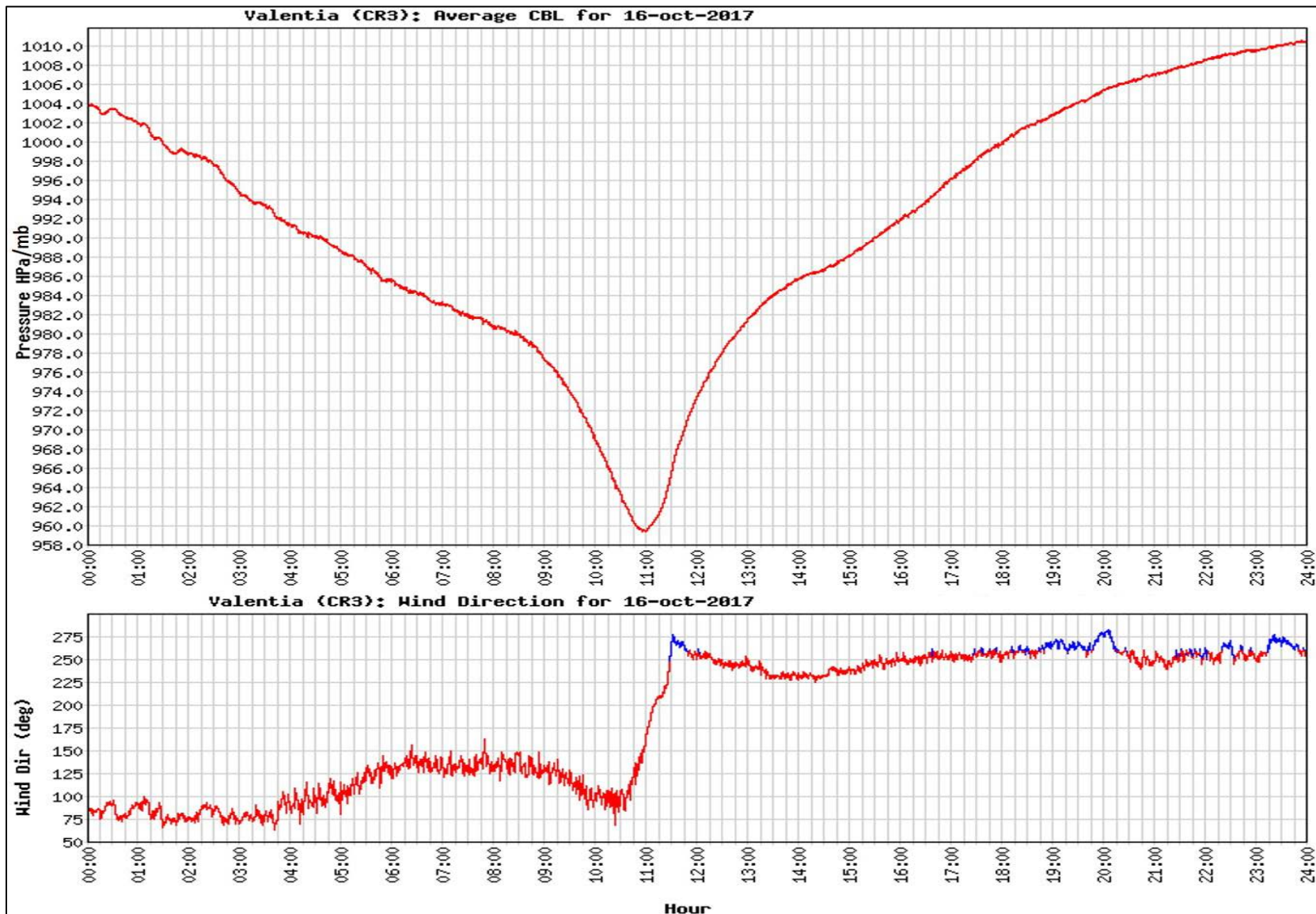


Figure 6. Pressure (top) and wind direction (bottom) time series for Valentia Observatory, Ireland, on 16 October 2017. Ophelia passed over the site as a post-tropical/extratropical cyclone at approximately 1100 UTC with a pressure of 959.3 mb (hPa). Graphics courtesy of Met Éireann (Irish National Meteorological Service).

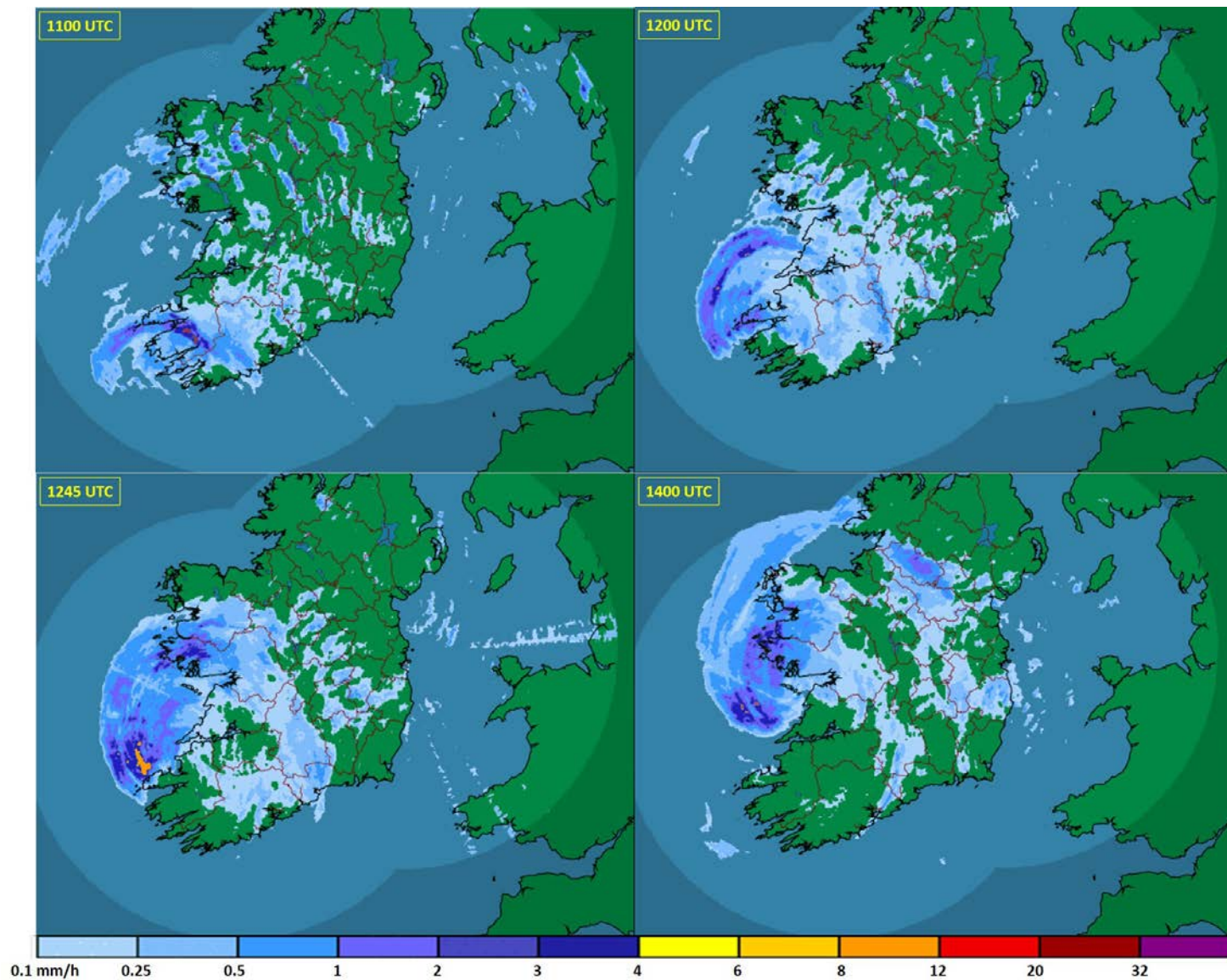


Figure 7. Radar reflectivity data showing extratropical Ophelia's trek along and near the southwestern coast of Ireland on 16 October 2017. Post-tropical Ophelia made landfall near Valentia Island around 1100 UTC. Radar-derived rainfall rates (mm/h) indicated by the legend along the bottom of the imagery. Radar data courtesy of Met Éireann (Irish National Meteorological Service).

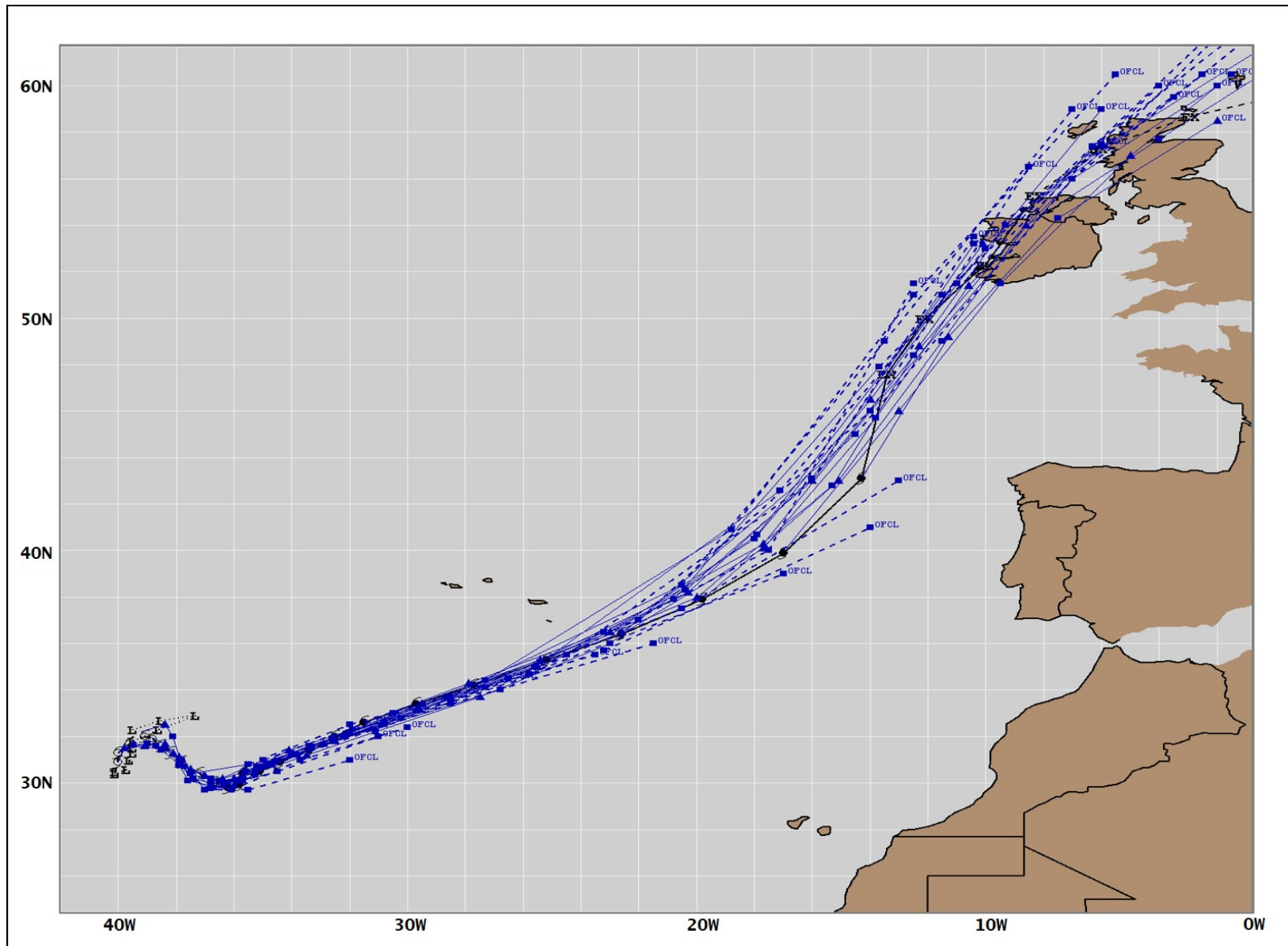


Figure 8. Selected official track forecasts (dashed blue lines, with 0, 12, 24, 36, 48, 72, 96, and 120 h positions indicated) for Hurricane Ophelia, 9–15 October 2017. The best track is given by the black line with positions given at 6 h interval.

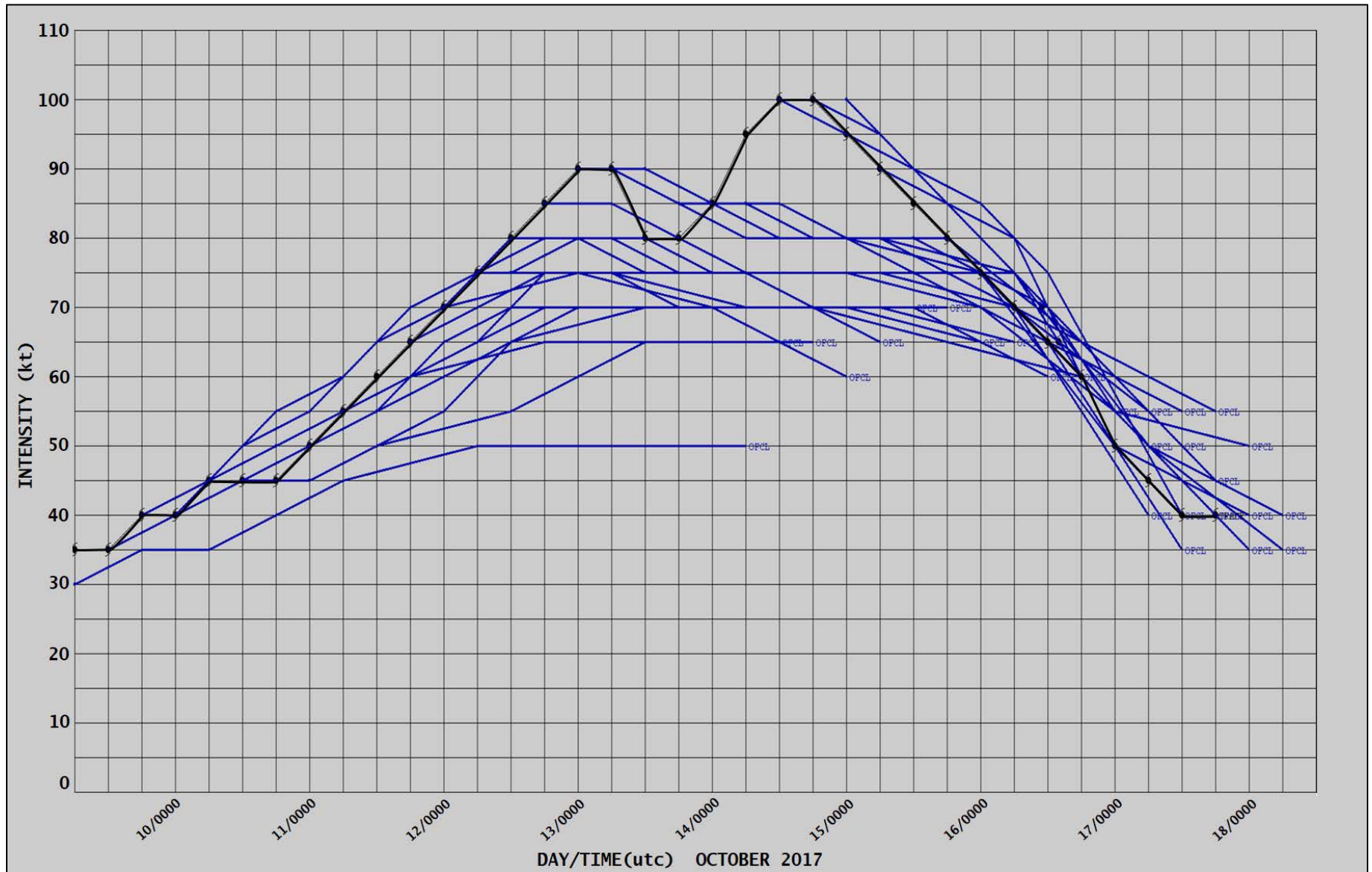


Figure 9. NHC intensity forecasts (solid blue lines) during the period 0600 UTC 9 October to 1800 UTC 15 October 2017 when Ophelia was a tropical cyclone. The best track is given by the solid black line with positions given at 6-h intervals.