NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE OLAF

(EP192015)

15 – 27 October 2015

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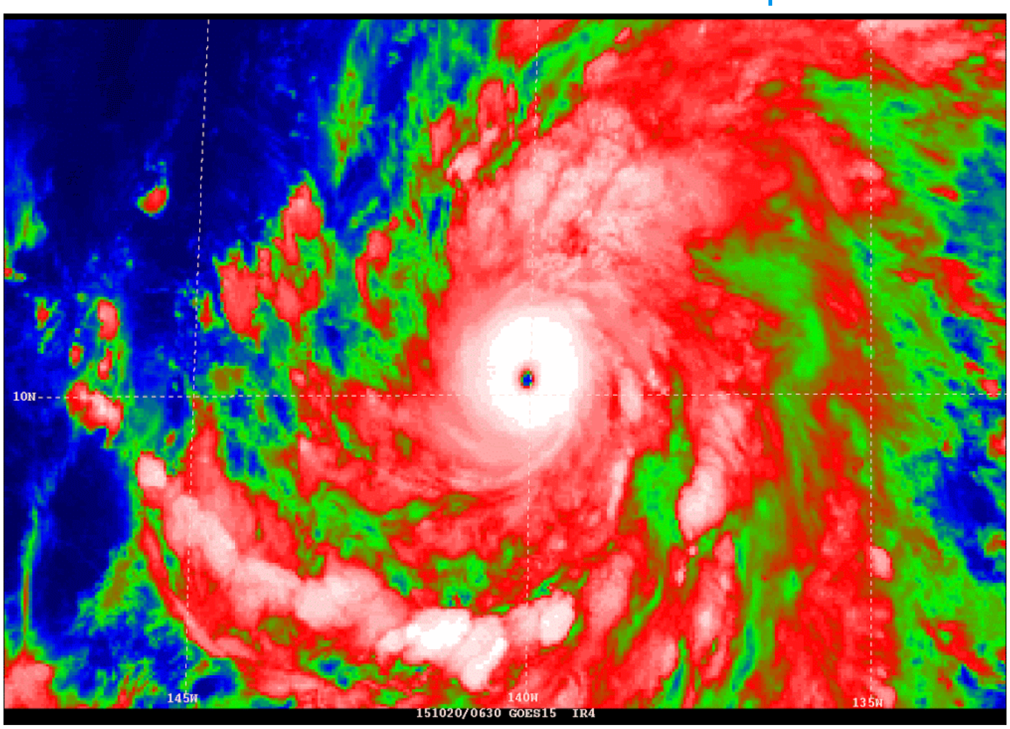
6 September 2016[1]



NOAA GOES-15 INFARED SATELLITE IMAGE OF HURRICANE OLAF AT 0630 UTC 20 OCTOBER 2015.

Olaf was an unusually long-lasting October hurricane that formed much farther southwest than average and stayed out at sea. Olaf has the distinction of being the only tropical cyclone on record to move from the eastern Pacific to the central Pacific and back again.

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[1] Original report date 9 February 2016. Report updated to include CPHC verification 6 September 2016.

Hurricane Olaf

15 – 27 OCTOBER 2015

SYNOPTIC HISTORY

The genesis of Olaf can be traced to a wave that left the west African coast on 24 September. The wave produced a fair amount of convection for a few days, but lost all thunderstorm activity in the central Atlantic on 27 September. After moving slowly westward during the next several days, the wave entered the eastern Pacific on 7 October. Convection greatly increased the next day, and a broad low formed by late on 9 October at a low latitude south of 10°N. The thunderstorm activity, however, was generally limited over the next several days, and the low remained broad while it moved westward. On 14 October, convection increased and the low became better defined, leading to the formation of a tropical depression by 0000 UTC 15 October about 860 n mi south-southwest of Cabo San Lucas, Mexico. 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[2].

The newly formed tropical depression moved westward to west-southwestward for a couple of days due to a ridge building northwest of the cyclone. Despite seemingly favorable environmental conditions, the depression remained disorganized, with the low-level circulation becoming somewhat elongated to the south and not well aligned with the mid-level center. Eventually the low- and mid-level centers aligned, convection consolidated near the center, and banding features increased, and the depression strengthened into a tropical storm about 48 h after genesis. Late on 17 October, when Olaf was in a warm-water, low-shear environment, it began to rapidly intensify. Concurrently, Olaf began to move slightly north of due west around a distant ridge of high pressure. The tropical storm became a hurricane at 9.3°N, an unusually low latitude, around 0600 UTC 18 October around the time that an eye was noted on shortwave infrared (night-visible) images. The small hurricane continued to rapidly strengthen and reached major hurricane status at 1200 UTC 19 October. Olaf had a pinhole eye on satellite imagery, with a central dense overcast that was only ~90 n mi across.

About the time it moved into the central Pacific basin, Olaf reached its peak intensity of 130 kt near 0600 UTC 20 October (cover). The hurricane maintained that intensity for the next 12 h while it moved west-northwestward around the southern periphery of a large deep-layer ridge to the north. Although Olaf was in a favorable environment of sea surface temperatures (SSTs) in excess of 29°C and low vertical wind shear, it weakened to category 3 strength early on 21 October, possibly the result of an eyewall replacement cycle and/or the entrainment of some drier mid-level air. The next day, as Olaf moved northwestward it developed a large, nearly 30-n mi-

[2] 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.

wide eye, and by 1800 UTC 22 October it weakened below category 3 strength in response to another eyewall replacement cycle and higher northwesterly shear.

The hurricane made a turn toward the north late on 22 October due to an upper-level trough digging to the north of Hawaii, which weakened the deep-layer ridge. This change in course led to a reduction of shear, and Olaf re-strengthened over SSTs of 28-29°C to an intensity of 105 kt on 23 October. An increase in vertical wind shear, in combination with SSTs near 27°C and entrainment of drier mid-level air, led to rapid weakening of the tropical cyclone on 24 October. Olaf weakened to an intensity of 80 knots by 0600 UTC on 25 October and kept that intensity for the remainder of the day as the shear was once again lessened due to a weakening of the mid-latitude westerlies north of the cyclone. Olaf was able to maintain an eye during this time, although it was ragged. By 0000 UTC 26 October, the approach of a strong upper-level trough from the northwest of the system increased the vertical wind shear, and accelerated the cyclone northeastward. Olaf weakened to a tropical storm by 1200 UTC on 26 October, just prior to its re-entry into the eastern Pacific basin.

Olaf continued to lose strength on 27 October due to the strong shear and cool waters. Olaf lost all deep convection by 1200 UTC, becoming post-tropical about 1025 n mi west-southwest of San Diego, California. The system weakened further and looped back southwestward under the influence of a low-level ridge, opening up into a trough by 1800 UTC 28 October.

METEOROLOGICAL STATISTICS

Observations in Olaf (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB), the Central Pacific Hurricane Center (CPHC), the Joint Typhoon Warning Center (JTWC) and objective Advanced Dvorak Technique (ADT) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison (UW-CIMSS). 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 the hurricane.

The estimated 130-kt peak intensity of Olaf in the eastern Pacific basin is based on Dvorak satellite intensity estimates from TAFB and SAB, and ADT estimates from UW-CIMSS.

The estimated 130-kt peak intensity of Olaf in the central Pacific basin is based on Dvorak satellite intensity estimates from CPHC, JTWC and SAB. The minimum central pressure of 938 mb at 0600 UTC 20 October is based on the Knaff-Zehr-Courtney (KZC) pressure-wind relationship for an intensity of 130 knots.

Olaf was unusually strong for being so far south in the basin. It is the lowest-latitude hurricane on record in the eastern Pacific, and it is also the only category 4 hurricane on record south of 10°N. This intensity is especially notable given that before Olaf, there were no category 2 or stronger hurricanes in the historical record south of 10°N. Olaf also has the distinction of being the only tropical cyclone on record to move from the eastern Pacific to the central Pacific and back into the eastern Pacific.

There were no ship reports or surface observations of winds of tropical storm force associated with Olaf.

High surf generated by Olaf led to surf heights of 10 to 20 feet along east-facing shores of the Big Island of Hawaii, 8 to 12 feet along east-facing shores of Maui, and 6 to 9 feet along the south facing shores of the other Islands between 21 and 26 October. A stretch of Highway 137 on the southeast side of the Big Island of Hawaii, was inundated by eight inches of water from high surf on 22 October.

CASUALTY AND DAMAGE STATISTICS

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

FORECAST AND WARNING CRITIQUE

Olaf's genesis was generally well forecast overall (Table 2). The system that became Olaf was introduced into the Tropical Weather Outlook (TWO) with a low (< 40%) probability of formation during the next 5 days 156 h before genesis, and it was included in the 48-h TWO 126 h before formation. The lead time on the 48-h TWO, however, is a little misleading because the low weakened enough several days before genesis to drop the probabilities to zero. It was then included again in the 48-h TWO 42 h before genesis. The probability reached the high category (> 60% chance of formation) 78 h before genesis in the 5-day TWO and 6 h before formation in the 48-h TWO.

A verification of NHC official track forecasts for Olaf is given in Table 3a. Official forecast track errors were near the mean official errors for the previous 5-yr average through 24 h, then were above that period through 120 h. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Almost all of the model guidance had a significant northeastward bias with the first four days of forecasts of Olaf (Fig. 4) except for the UKMET, which led to the large errors at long range. Overall the official forecast did well compared to most of the guidance. The UKMET (EGRI) model (Fig. 4d) was by far the best overall model for this cyclone, while most of the GFS-based guidance struggled.

A verification of NHC official intensity forecasts for Olaf is given in Table 4a. Official forecast intensity errors were not significantly different than the mean official errors for the previous 5-yr period, except at 120 h. Overall, the Olaf intensity forecasts were quite remarkable given the very large SHIFOR (OCD5) errors, which were twice as large as average by 96 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official forecast bested all of the guidance through 72 h, although the errors were not particularly low. The dynamical models (GHMI/HWFI) generally had a poorer performance than the statistical-dynamical models (DSHP/LGEM) for Olaf.

A verification of CPHC official track forecasts for Olaf is given in Table 5a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at all forecast hours. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. Overall, the models performed well with respect to the track of Olaf, with both the consensus and dynamical guidance having varying degrees of success. The multi-model consensus (TVCN) generally performed the best, while the GFEX (GFS/ECMWF average), EMXI, HWFI and CMCI all showed some skill at times against the official forecast during Olaf.

A verification of CPHC official intensity forecasts for Olaf is given in Table 6a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period, except at 12 and 24 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. Overall, the official intensity errors were quite low, and a marked improvement on the forecasts from both the statistical and dynamical models. The official forecast bested the consensus guidance (IVCN), the dynamical models (GHMI/HWFI), and the statistical-dynamical models (DSHP/LGEM) at almost every forecast hour during Olaf.

There were no coastal watches or warnings associated with Olaf.

Table 1. Best track for Hurricane Olaf, 15-27 October 2015.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
15 / 0000	10.2	117.0	1006	30	tropical depression
15 / 0600	10.3	118.2	1006	30	"
15 / 1200	10.3	119.3	1006	30	"
15 / 1800	10.2	120.5	1006	30	"
16 / 0000	10.0	121.8	1006	30	"
16 / 0600	9.8	123.1	1006	30	"
16 / 1200	9.6	124.3	1006	30	"
16 / 1800	9.5	125.6	1005	30	"
17 / 0000	9.4	126.8	1004	35	tropical storm
17 / 0600	9.3	127.9	1003	45	"
17 / 1200	9.2	129.0	999	50	"
17 / 1800	9.1	129.9	999	50	"
18 / 0000	9.2	130.7	994	55	"
18 / 0600	9.3	131.6	991	65	hurricane
18 / 1200	9.4	132.6	988	70	"
18 / 1800	9.5	133.8	985	75	"
19 / 0000	9.6	135.0	978	85	"
19 / 0600	9.7	136.1	970	95	"
19 / 1200	9.8	137.2	962	105	"
19 / 1800	9.9	138.2	954	115	"
20 / 0000	10.0	139.1	954	115	"
20 / 0600	10.2	140.0	938	130	"
20 / 1200	10.4	140.9	938	130	"
20 / 1800	10.7	141.8	938	130	"
21 / 0000	10.9	142.6	943	125	"
21 / 0600	11.2	143.3	952	115	"
21 / 1200	11.6	144.1	958	105	"
21 / 1800	11.9	144.7	958	105	"

22 / 0000	12.3	145.3	958	105	"
22 / 0600	12.7	145.7	957	105	"
22 / 1200	13.2	146.1	961	100	"
22 / 1800	13.5	146.3	963	95	"
23 / 0000	14.0	146.3	961	100	"
23 / 0600	14.8	146.3	958	105	"
23 / 1200	15.6	146.3	957	105	"
23 / 1800	16.5	146.3	957	105	"
24 / 0000	17.4	146.1	956	105	"
24 / 0600	18.3	145.9	956	105	"
24 / 1200	19.0	145.6	955	105	"
24 / 1800	19.7	145.1	964	95	"
25 / 0000	20.3	144.5	970	85	"
25 / 0600	20.8	144.2	974	80	"
25 / 1200	21.5	144.0	974	80	"
25 / 1800	22.1	143.6	974	80	"
26 / 0000	22.9	143.0	977	75	"
26 / 0600	23.6	142.4	983	65	"
26 / 1200	24.4	141.5	989	55	tropical storm
26 / 1800	25.3	139.5	992	50	"
27 / 0000	25.9	137.9	995	45	"
27 / 0600	26.2	136.6	1000	45	"
27 / 1200	26.6	135.5	1000	40	low
27 / 1800	27.1	134.8	1002	35	"
28 / 0000	26.9	134.5	1002	35	"
28 / 0600	26.6	134.5	1004	30	"
28 / 1200	26.2	135.0	1006	25	"
28 / 1800					dissipated
20 / 0600	10.2	140.0	938	130	minimum pressure and maximum wind

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%)	126	156
Medium (40%-60%)	24	126
High (>60%)	6	78

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Olaf. 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	25.0	**35.9**	53.6	77.8	136.3	196.3	247.4
OCD5	35.8	62.5	91.2	113.2	166.0	236.5	331.2
Forecasts	23	22	22	22	22	22	22
OFCL (2010-14)	23.4	36.4	47.2	59.4	89.0	123.6	159.5
OCD5 (2010-14)	36.6	74.2	116.5	159.7	245.6	331.1	427.4

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Olaf during the time Olaf was in NHC's area of responsibility. 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	23.6	35.4	54.8	80.8	139.8	197.4	243.9
OCD5	35.0	62.5	91.0	112.9	164.8	236.6	332.5
GFSI	29.4	44.6	67.1	94.4	166.4	240.9	295.2
GHMI	32.6	54.9	82.8	115.0	193.1	276.8	357.3
HWFI	28.1	47.3	66.7	89.1	148.5	213.7	288.3
EGRI	**19.8**	**25.3**	**28.5**	**33.6**	**59.5**	**76.2**	**108.0**
EMXI	24.7	38.9	60.4	83.7	**135.0**	**176.2**	**219.5**
CMCI	42.0	70.2	91.9	111.2	**138.1**	**162.0**	**182.2**
AEMI	29.6	48.5	73.2	101.7	169.7	236.8	282.0
TVCE	25.8	38.6	57.6	**79.7**	**134.4**	**187.0**	**232.9**
LBAR	37.6	65.0	95.5	124.0	191.7	253.8	291.3
BAMD	38.5	59.8	86.8	116.2	189.6	278.8	338.6
BAMM	31.2	47.3	64.1	84.2	146.0	235.9	307.5
BAMS	44.3	71.8	93.2	105.9	**135.6**	**179.4**	**234.2**
Forecasts	22	21	21	21	21	21	21

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Olaf. 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	5.9	**9.3**	13.6	**13.4**	**15.0**	**15.0**	20.7
OCD5	8.8	14.6	19.7	24.2	28.9	42.5	43.4
Forecasts	23	22	22	22	22	22	22
OFCL (2010-14)	5.9	9.8	12.5	14.0	15.5	16.3	14.9
OCD5 (2010-14)	7.7	12.8	16.4	18.8	21.1	20.9	19.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Olaf during the time that it was in NHC's area of responsibility. Errors smaller than the NHC official forecast are shown in boldface type.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	5.9	9.3	13.6	13.4	15.0	15.0	20.7
OCD5	8.8	14.6	19.7	24.2	28.9	42.5	43.4
GFSI	8.7	14.0	17.3	20.6	21.0	**13.7**	**16.5**
EMXI	10.0	18.0	25.6	29.5	34.8	34.4	35.7
GHMI	13.3	23.0	29.5	29.5	25.0	27.1	23.2
HWFI	9.8	15.8	17.8	19.7	22.2	27.1	27.1
DSHP	8.0	13.6	18.8	21.7	21.4	16.2	**17.5**
LGEM	7.4	12.0	16.5	18.0	19.8	**14.2**	**16.3**
IVCN	9.0	14.2	17.5	19.1	18.7	18.6	**20.6**
Forecasts	23	22	22	22	22	22	22

Table 5a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Olaf. Mean OFCL errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr mean are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**24.6**	**36.6**	**48.3**	**68.4**	**116.8**	**109.5**	**131.3**
OCD5	38.7	87.7	151.8	227.1	488.7	780.0	1075.4
Forecasts	25	25	23	21	17	13	9
(CP) OFCL (2010-14)	27.9	44.1	56.7	73.9	132.3	183.7	258.9

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Olaf. Errors smaller than the CPHC 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	25.4	37.4	48.3	68.0	119.6	111.0	136.0
OCD5	39.8	89.6	154.7	230.9	494.9	791.1	1095.9
BAMD	54.5	120.7	182.4	226.6	274.3	344.3	306.5
BAMM	37.3	78.1	120.8	152.9	222.3	299.6	354.2
BAMS	47.5	86.6	123.3	176.7	331.0	397.9	436.0
HWFI	29.0	49.2	65.3	70.0	**84.9**	**77.6**	**93.4**
GHMI	**24.3**	44.3	69.7	89.7	143.4	148.4	217.6
AVNI	**23.1**	41.9	64.9	88.5	161.6	171.9	154.7
AEMI	**23.5**	40.6	58.8	89.7	169.6	185.5	205.3
EGRI	**23.9**	41.5	71.2	106.6	160.1	152.2	251.1
NGXI	31.5	54.0	71.8	95.6	125.2	124.7	189.8
CMCI	27.9	54.4	84.3	117.4	163.6	**95.2**	**97.8**
EMXI	25.7	44.8	**48.2**	**67.7**	**112.4**	146.3	163.6
TVCN	**21.2**	**33.3**	**45.6**	**65.5**	**118.6**	113.2	**119.8**
GFEX	**22.0**	**36.4**	48.4	72.6	132.3	154.2	140.1
Forecasts	24	24	22	20	16	12	8

Table 6a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Olaf. Mean OFCL errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr mean are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	6.8	9.0	**9.8**	**9.8**	**10.6**	**11.5**	**10.0**
OCD5	8.9	12.9	18.7	23.5	36.3	24.2	8.8
Forecasts	25	25	23	21	17	13	9
(CP) OFCL (2010-14)	4.8	8.6	11.6	13.8	18.5	19.3	20.4

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Olaf. Errors smaller than the CPHC 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	6.3	8.3	9.3	9.3	10.9	10.0	9.3
OCD5	9.0	13.3	19.1	24.0	35.9	24.9	**8.1**
HWFI	6.9	**7.4**	**9.0**	10.6	15.2	16.0	15.0
GHMI	10.3	15.0	16.9	14.2	13.6	14.9	18.1
AVNI	7.0	10.3	13.7	14.9	20.3	25.5	40.3
EMXI	**6.1**	11.3	17.3	19.5	26.9	33.1	49.4
IVCN	7.5	10.4	11.9	12.9	13.0	11.6	**5.4**
SHIP	8.8	14.0	17.8	21.4	25.9	26.2	17.7
DSHIP	8.8	14.0	17.8	21.4	25.9	26.2	17.7
LGEM	8.5	13.4	18.3	22.3	26.1	29.0	23.4
Forecasts	24	24	22	20	16	10	7

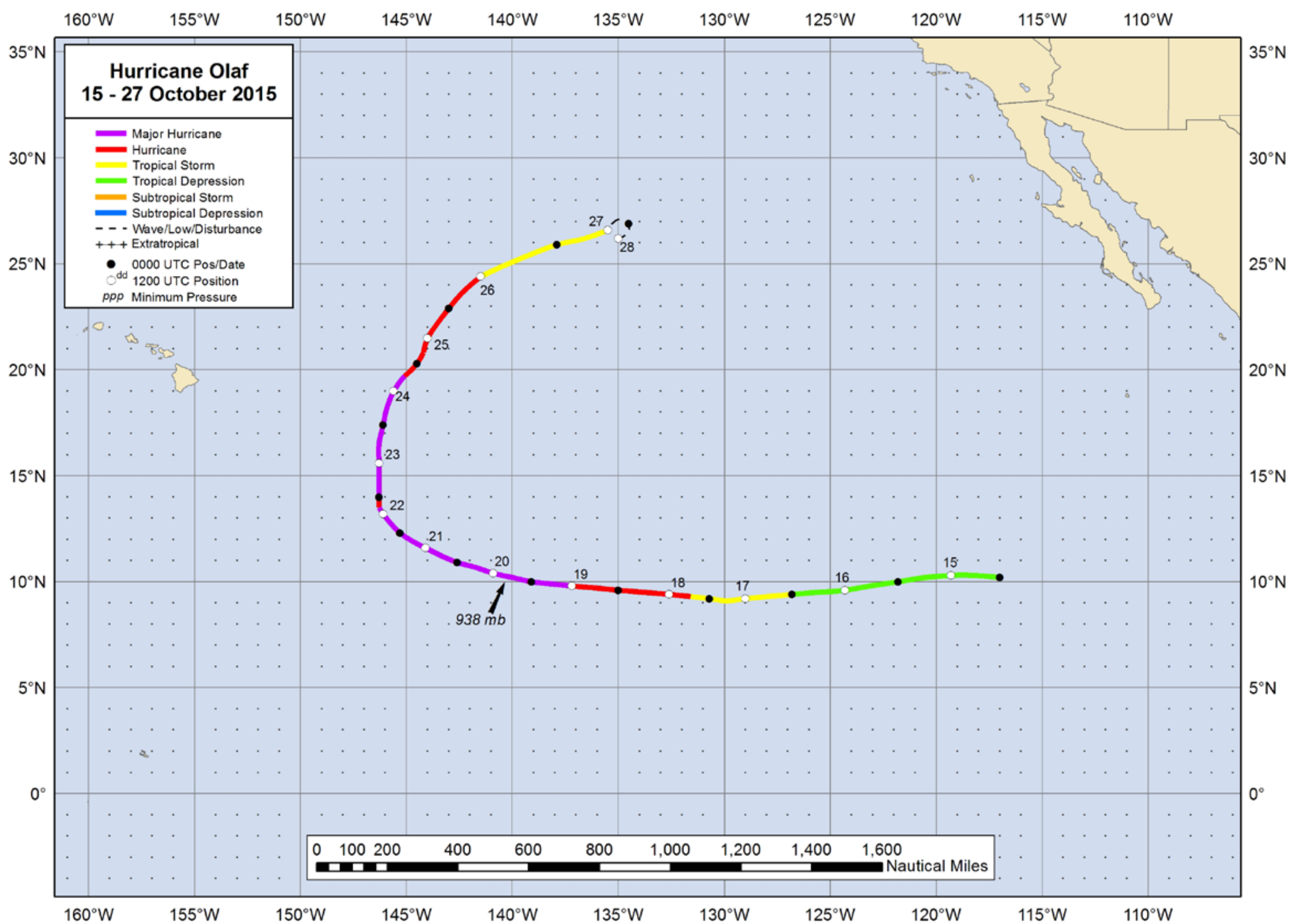

Figure 1. Best track positions for Hurricane Olaf, 15-27 October 2015.

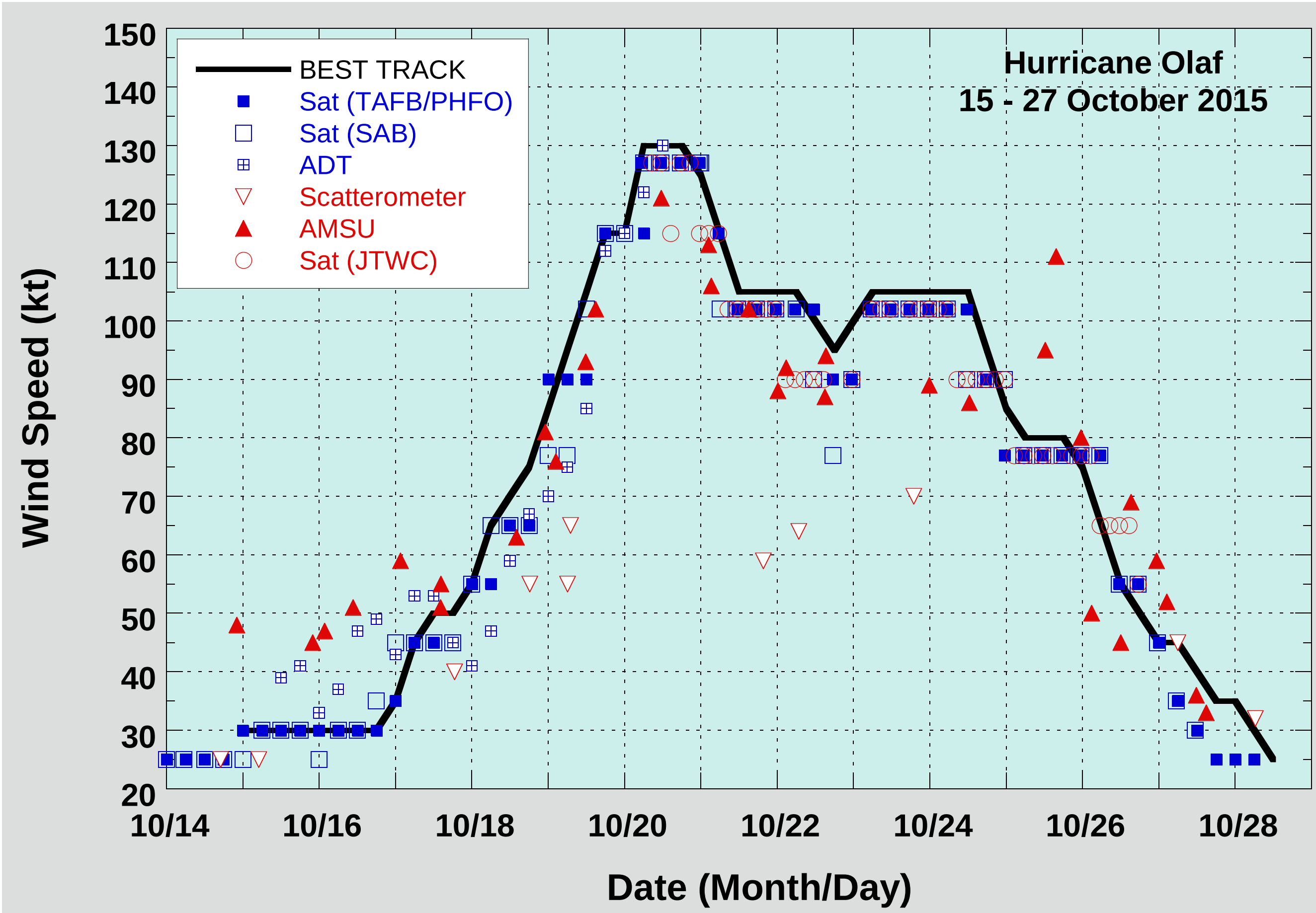

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Olaf. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique.

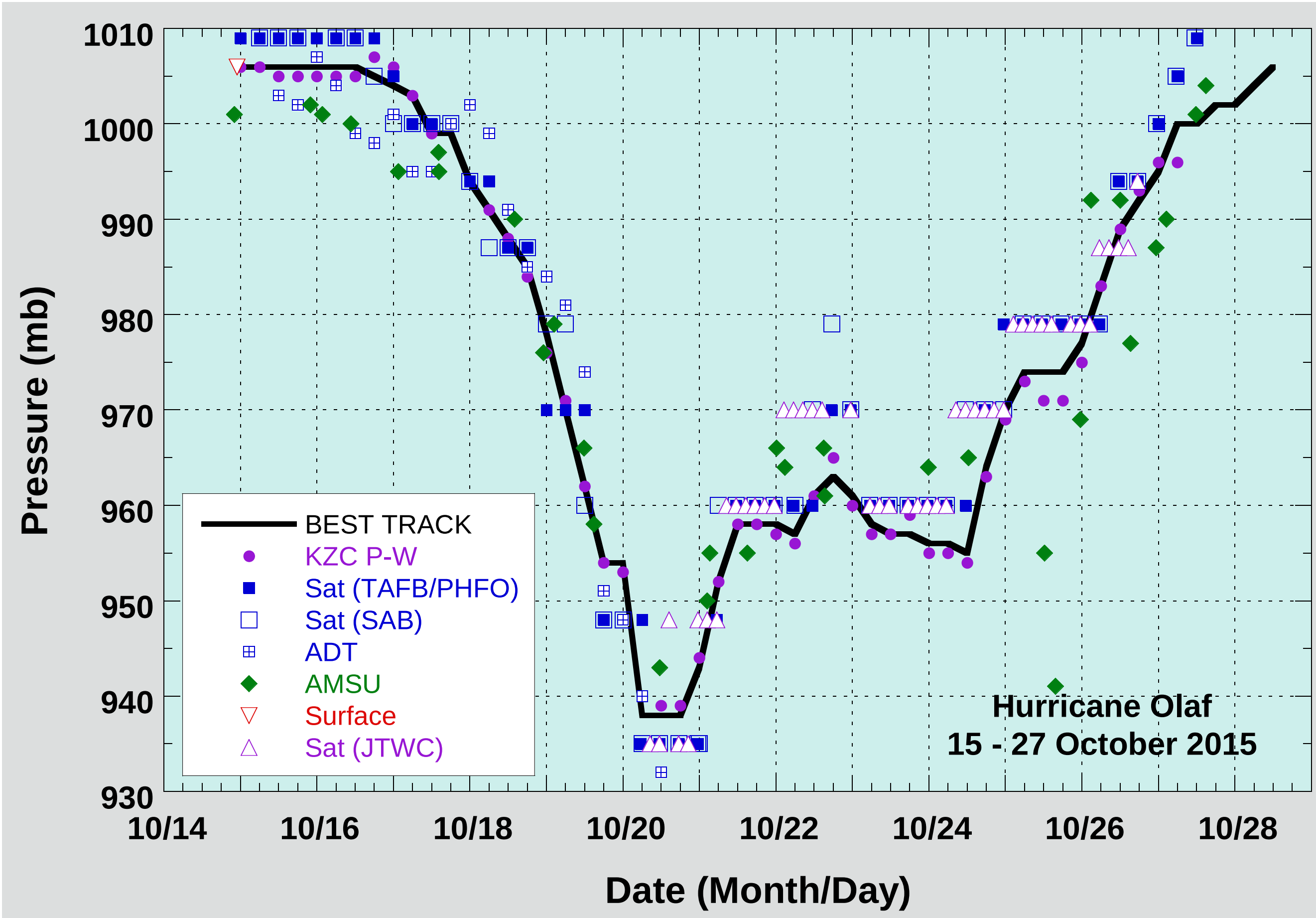

Figure 3. Selected pressure observations and best track minimum central pressure curve for Olaf. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship.

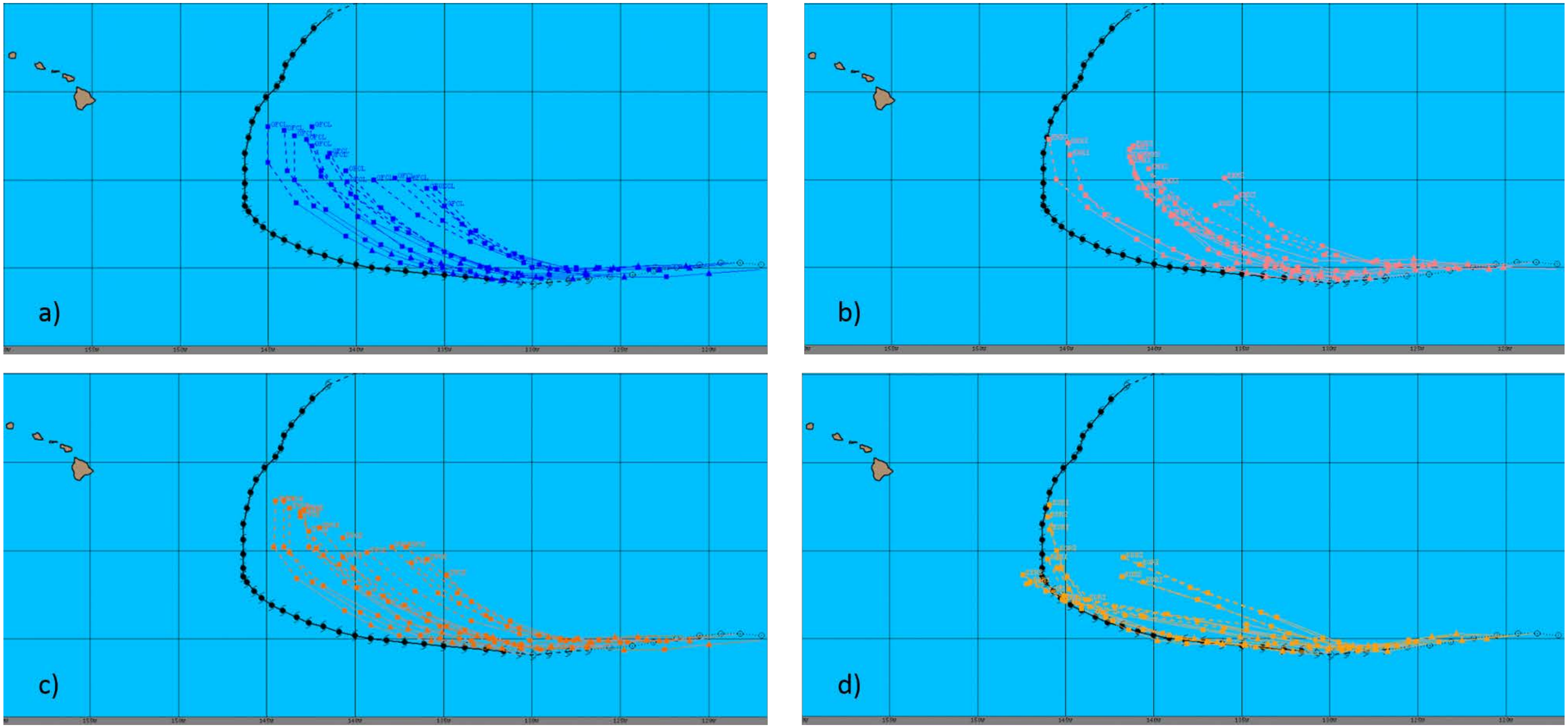

Figure 4. Olaf best-track (black) versus forecasts from 0000 UTC 15 October to 1800 UTC 18 October 2015 for: a) OFCL, b) ECMWF model, c) TVCE, and d) UKMET model. Note the significant northeastward bias in all forecasts except for those from the UKMET.