CENTRAL PACIFIC HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE KILO

(CP032015)

22 August – 10 September 2015

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Central Pacific Hurricane Center
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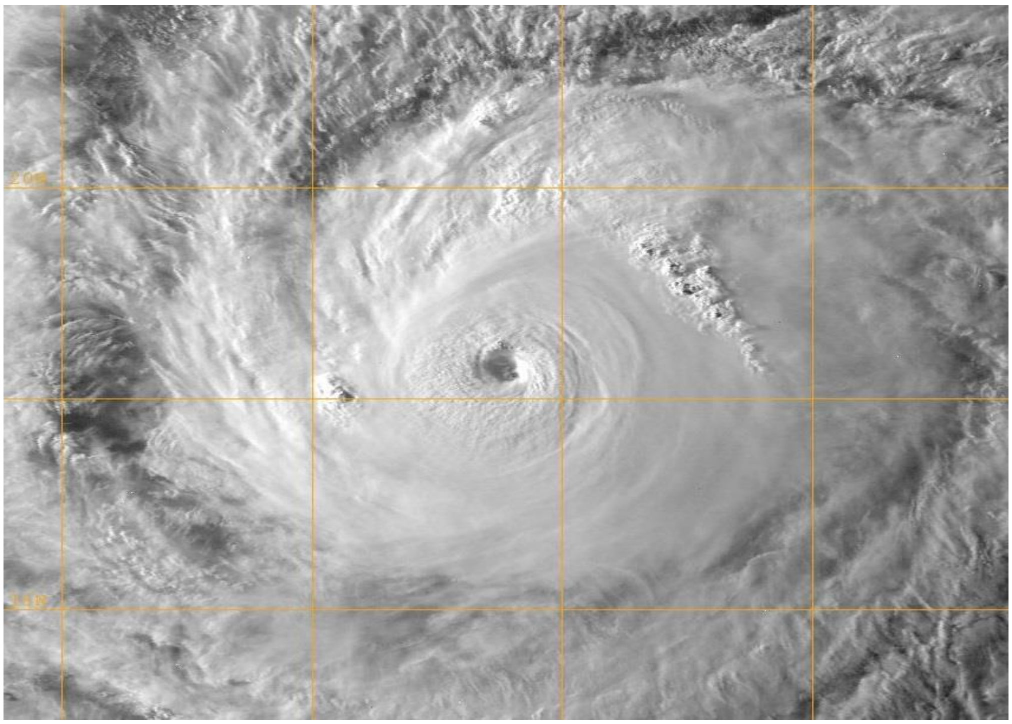

FIGURE 1. GOES-15 VISIBLE IMAGE OF CATEGORY FOUR HURRICANE KILO AS IT APPROACHED THE DATE LINE AT 0500 UTC 30 AUGUST. IMAGE COURTESY OF NRL MONTEREY.

Kilo was a long-lived tropical cyclone that developed slowly at first within the central Pacific, and eventually rapidly intensified to a major hurricane as it approached the International Date Line. Note that this report only covers the portion of the tropical cyclone's life cycle within the central north Pacific basin.

Hurricane Kilo

22 AUGUST – 10 SEPTEMBER 2015

SYNOPTIC HISTORY

Kilo was a long-lived tropical cyclone that developed within the central North Pacific (CNP) during the remarkable and record-setting 2015 hurricane season. A strong warm-phase El Nino Southern Oscillation (ENSO) event brought anomalously warm ocean temperatures, unusually low vertical wind shear, and increased atmospheric moisture, which led to a record 15 tropical cyclones within the CNP during the season. With a record-breaking number of CNP TC, 2015 had more days with multiple hurricanes in the basin than in all other years combined since 1970. As seen in Figure 2, sea surface temperatures (SST) were anomalously warm throughout the basin, and SSTs near Hawaii were the warmest all-time for any month over the past 60+ years, having smashed the previous record by ~0.9C.

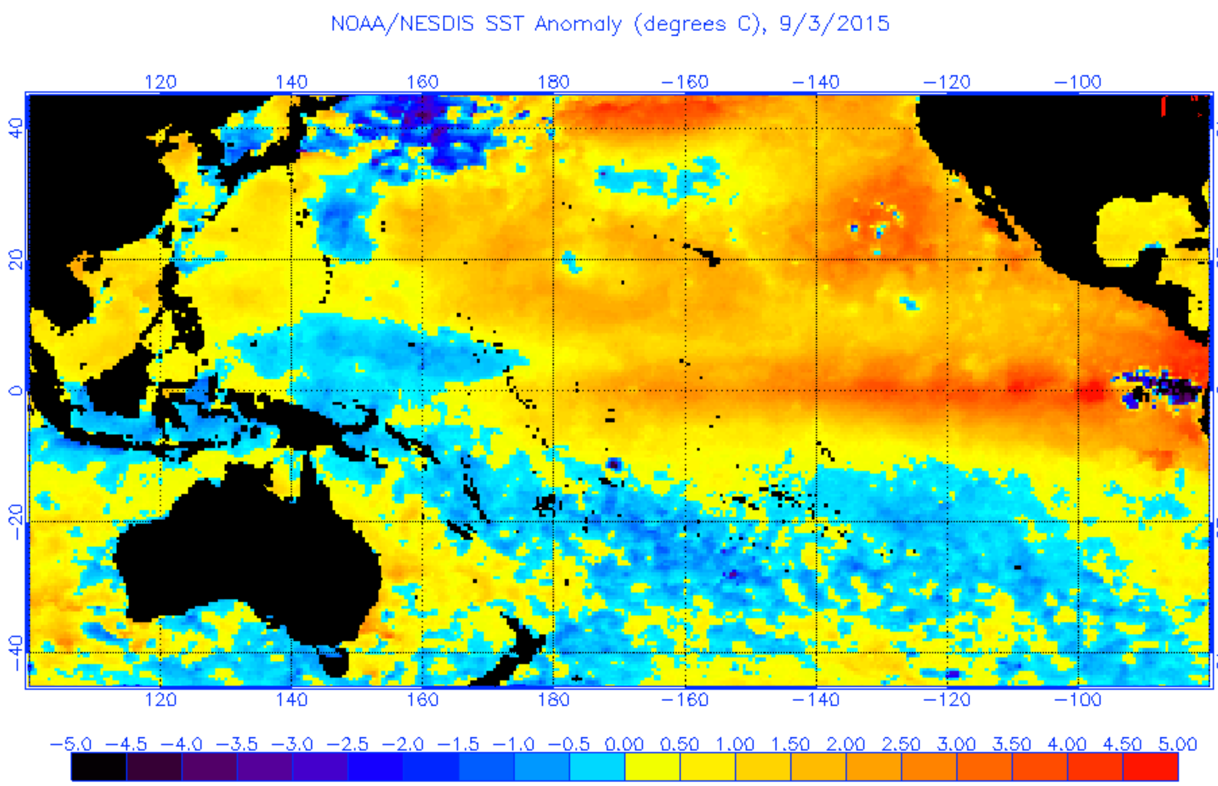

FIGURE 2. SST ANOMALY CHART - 3 SEPT 2015 (COURTESY NOAA/NESDIS)

The low-level circulation center (LLCC) associated with Kilo was initially exposed, elongated, and slow to consolidate, despite being over very warm water. Easterly vertical wind shear supported by a low- and mid-level ridge centered to the north and northeast of the cyclone was likely responsible, with the bulk of the associated convection initially located to the west and northwest of the LLCC. Observations from reconnaissance aircraft supported satellite observations that indicated that Kilo was initially weak and poorly organized, but the cyclone later rapidly intensified to a major hurricane in the western portion of the CNP.

The disturbance that became Kilo was initially identified on 17 August, about 1000 n mi southeast of the Big Island of Hawaii. The disturbance developed within an east to west oriented low-level trough that extended between 135°W and 160°W along 8°N, with low-level vorticity associated with the trough responsible for spawning the disturbance and associated convection. The disturbance remained poorly organized as it initially moved little through 18 August, and moved northeast out of the trough on 19 and 20 August. The disturbance produced intermittent convection, mainly to the west of the LLCC. However, in the early morning hours of 20 August, a burst of deep convection developed in association with the disturbance, and operationally, Tropical Depression Kilo officially formed around 1800 UTC 20 August. However, this convection later dissipated on 20 August, and a poorly organized and elongated LLCC emerged well east of the weakening convection, and tracked north-northeast as associated convection continued to remain well west of an elongated LLCC.

Sporadic deep convection continued to move rather quickly toward the west-northwest through 21 August, with an exposed LLCC remaining east of the convection. The disturbance was steered by a low- and mid-level ridge to the north, with the embedded in an environment characterized by easterly vertical wind shear. Around 0600 UTC 22 August, deep convection became increasingly co-located with the still elongated but consolidating LLCC as easterly shear apparently relaxed, and the best track indicates this as the time that Tropical Depression Kilo officially formed.

Tropical Depression Kilo continued to move toward the west-northwest through 0600 UTC 24 August, along the south and southwestern periphery of a mid-level ridge, with the associated easterly shear inhibiting further strengthening. Kilo's forward speed began to diminish as it neared the western edge of this weakening ridge around 1200 UTC 24 August, with Kilo moving toward the northwest and north. Steering currents became quite weak over the subsequent 24 hours, and Kilo remained poorly organized, with the exposed LLCC noted in satellite imagery around 1200 UTC 25 August. Slow-moving Kilo gradually increased in organization over the next 24-48 hours as a new mid-level ridge strengthening to the northwest of the cyclone began to impart a motion toward the southwest, and vertical wind shear diminished. Due to the forecast track taking Kilo close to Johnston Island, a tropical storm watch was issued at 0300 UTC 26 August when the center of Kilo was about 200 miles to the northeast, upgraded to a tropical storm warning at 0900 UTC 26 August.

Kilo intensified to a tropical storm at 1800 UTC 26 August as it drifted toward the southwest. By 0000 UTC 28 August, Kilo was moving west-southwest, and was close to hurricane strength as the center passed within about 35 miles north of Johnston Island, bringing tropical storm conditions to the island. As Kilo began to move away from Johnston Island, the tropical storm warning was discontinued at 2100 UTC 28 August. Kilo achieved hurricane status at 0600 UTC 29 August, as it was being steered to the west by a mid-level ridge to the north. With very warm water and light vertical wind shear, Kilo rapidly intensified from 65 kt to 110 kt in 12 hours, with peak intensity of 120 kt achieved at 0600 UTC 30 August. A slight weakening trend followed over the next 24 h, with little change in intensity over the following 24 h, allowing Kilo to maintain major hurricane MH status. An anticipated break in the mid-level ridge to the north of Kilo allowed it move toward the northwest as it approached the International Date Line, and Kilo crossed the Date Line between 1200 UTC and 1800 UTC 1 September, with subsequent forecasts issued by the Japan Meteorological Agency (JMA), and the Joint Typhoon Warning Center (JTWC).

While MH Kilo was in the western portion of the CNP basin, MH Ignacio was traversing the eastern portion of the basin, and MH Jimena was in the eastern Pacific. These three cyclones were part of a historic Pacific tropical cyclone event, as three concurrent MH had never before been observed east of the Date Line, at one point they were all Category 4 intensity. Prior to this, two concurrent Category 3 hurricanes, let alone Category 4, had never been recorded in the CNP.

Kilo was the third TC to cross the International Date Line in 2015, breaking the old record of two TCs, set in 1997. In all, Kilo traveled over 4,000 statute miles from its genesis point as a depression south of Hawaii to near the western Kuril Islands in Alaska.

METEOROLOGICAL STATISTICS

Observations in Kilo (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Satellite Analysis Branch (SAB), the Central Pacific Hurricane Center (PHFO), and the Joint Typhoon Warning Center (JTWC). Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from flights of the 53rd Weather Reconnaissance Squadron (53WRS) 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 Global Precipitation Mission (GPM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also utilized in constructing the best track of Kilo.

Winds and Pressure

The 53WRS conducted four missions into Kilo while it was a tropical depression (22 August – 23 August). This was somewhat unusual as the 53WRS typically does not fly weak systems in the central Pacific. In the case of Kilo, aircraft reconnaissance was requested when forecast models indicated that the incipient cyclone could pose a significant threat to the main Hawaiian Islands. These missions resulted in five center fixes, although the cyclone was rather disorganized and the low-level circulation center was not well-defined during these storm penetrations, some of which were conducted at an altitude of 1500 feet. The maximum flight-level wind measured was 45 kt at 0627 UTC 22 August, while the strongest SFMR surface wind measured was 33 kt at 1910 UTC 22 August. Reconnaissance missions were completed well before maximum intensity well southwest of the main Hawaiian Islands.

There were no ship or land-based reports of tropical-storm force or greater winds associated with Kilo. Despite passing very close to Johnston Island, there were no observations or reports of tropical-storm-force winds or other impacts from Kilo.

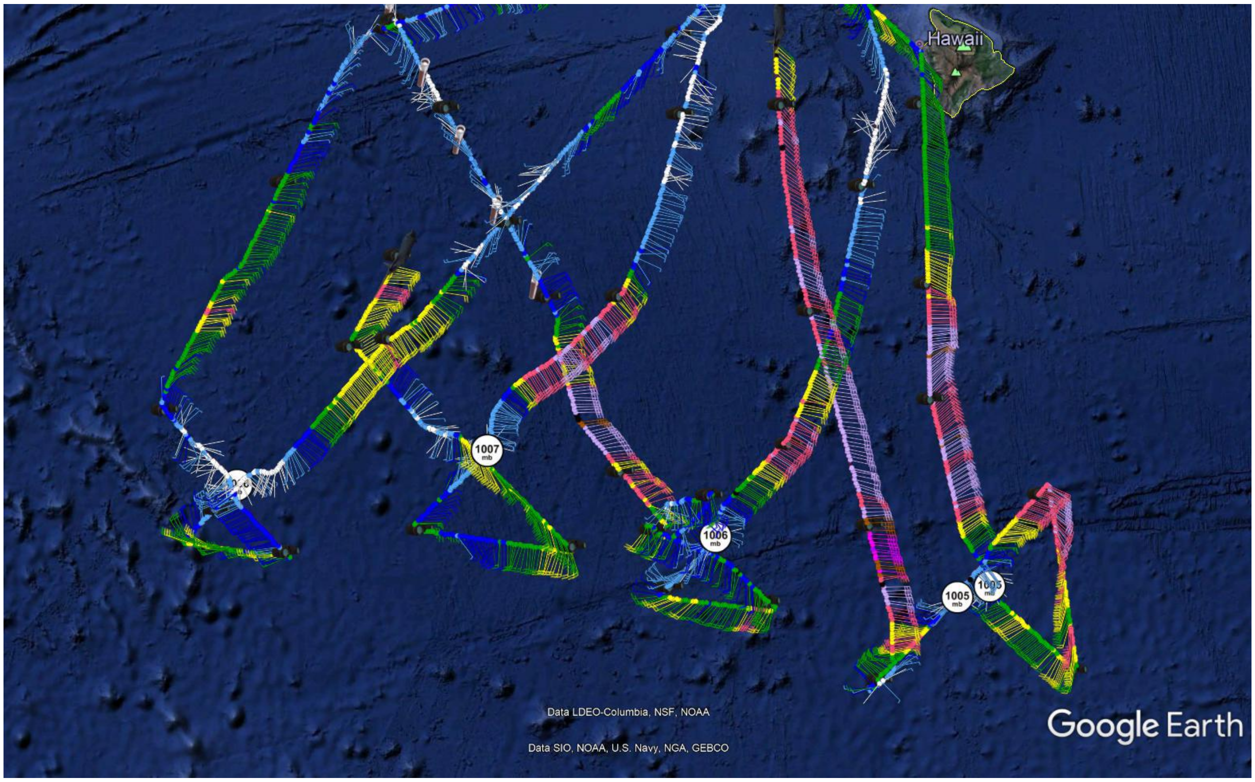

FIGURE 3. SUMMARY OF THE FOUR MISSIONS FLOWN INTO KILO ON 22 AND 23 SEPTEMBER (FROM TROPICALATLANTIC.COM)

CASUALTY AND DAMAGE STATISTICS

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

FORECAST AND WARNING CRITIQUE

The formation of Kilo was well anticipated, and perhaps over-anticipated, by global forecast models. A majority of the reliable guidance was consistent in precociously indicating significant development of the disturbance that would later become Kilo. Instead, Kilo was initially slow to organize and intensify, likely due to easterly shear. The incipient disturbance was operationally classified as a Tropical Depression at 2100 UTC 20 August, while the revised best track delays this designation until 0600 UTC 22 August due to lack of significant convective organization until that time. Kilo's precursor disturbance was first mentioned in CPHC's Tropical Weather Outlook (TWO) 78 h before the time of genesis, when it was given a low (30% or less) chance of development. The development chance was raised to medium (40%-60% chance) in the subsequent issuance of the TWO, or about 72 h before genesis. Finally, the probability of formation was raised to high (70% or greater chance) about 4 h before genesis. Table 2 lists the number of hours in advance of formation associated with the first CPHC TWO forecast in the indicated likelihood category.

A verification of CPHC official track forecasts for Kilo is given in Table 3a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at 72 h and 96 h, and greater than mean official errors at other times. The official forecast showed skilled at all forecast times when compared to OCD5. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The deterministic (GFSI) and ensemble guidance (AEMI) from the GFS model proved to be the most skillful in forecasting Kilo's track after 24 h, which also contributed to the success of the multi-model consensus TVCE. In fact, the most skillful track model through 48 h was TVCE, while GFSI performed best at 72 h to 120 h, and this guidance outperformed OFCL at all forecast hours.

A verification of CPHC official intensity forecasts for Kilo is given in Table 4a. As Kilo presented a difficult intensity forecast, official forecast intensity errors were significantly higher than the mean official errors for the previous 5-yr period at all forecast times, and were greater than OCD5 at 24h, 36 h and 48h. Global and regional forecast models, in addition to the statistical-dynamical SHIPS guidance, were indicating significant development in Kilo's early stages as it passed south of the main Hawaiian Islands, and this was reflected in the official forecast. Although Kilo did eventually intensify in the basin, official forecasts were too fast in anticipating intensification. A homogeneous comparison of official intensity errors with selected guidance models is presented in Table 4b, highlighting the large intensity forecast errors when compared to the previous 5-yr period. The interpolated HWRF model (HWFI), the decay SHIPS model (DSHP), and the intensity consensus IVCN had lower errors at all forecast times than the official forecasts.

Kilo was forecast to pass close and to the north of Johnston Atoll, prompting the issuance of a Tropical Storm Watch at 2100 UTC 23 August, which was upgraded to a Tropical Storm Warning at 0300 UTC 24 August. The center of Kilo remained north of the island, placing it in the weaker southern periphery of Kilo's circulation. After the threat to Johnston Atoll diminished, the Tropical Storm Warning was cancelled at 0300 UTC 25 August. The National Weather Service in Honolulu received word that the U.S. Dept. of Fish & Wildlife had personnel stationed on Johnston Island during Kilo's closest point of approach. Apparently, they had an uncalibrated barometer with them, but unfortunately this data was never received by the National Weather Service.

Table 1. Best track for Hurricane Kilo, 20 August – 1 September 2015.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage*
20/0000	10.0	145.3	1008	20	Disturbance
20/0600	10.3	146.7	1007	25	“
20/1200	10.6	148.0	1007	25	"
20/1800	11.0	149.1	1007	25	"
21/0000	11.6	150.0	1007	25	"
21/0600	12.2	150.9	1007	25	"
21/1200	12.8	152.0	1007	25	"
21/1800	13.2	153.2	1007	25	Low
22/0000	13.3	154.4	1006	25	"
22/0600	13.2	155.8	1005	30	Tropical Depression
22/1200	13.7	157.2	1005	30	"
22/1800	13.9	158.7	1005	30	"
23/0000	14.1	160.2	1005	30	"
23/0600	14.3	161.8	1005	30	"
23/1200	14.4	163.3	1005	30	"
23/1800	14.5	164.6	1005	30	"
24/0000	14.6	165.8	1005	30	"
24/0600	15.0	166.8	1005	30	"
24/1200	15.7	167.2	1005	30	"
24/1800	16.5	167.2	1005	30	"
25/0000	17.3	167.2	1006	25	"

25/0600	18.0	167.2	1006	25	"
25/1200	18.3	167.2	1006	25	"
25/1800	18.5	167.2	1006	25	"
26/0000	18.7	167.3	1005	30	"
26/0600	18.7	167.5	1005	30	"
26/1200	18.5	167.6	1005	30	"
26/1800	18.3	167.7	1004	35	Tropical Storm
27/0000	18.1	167.8	1003	40	"
27/0600	18.0	167.9	1001	45	"
27/1200	17.9	168.0	996	50	"
27/1800	17.7	168.3	992	55	"
28/0000	17.5	168.8	990	60	"
28/0600	17.4	169.5	990	60	"
28/1200	17.4	170.4	990	60	"
28/1800	17.5	171.3	990	60	"
29/0000	17.6	172.1	990	60	"
29/0600	17.7	173.0	985	65	Hurricane
29/1200	17.8	173.9	976	80	"
29/1800	17.9	174.8	952	110	"
30/0000	18.1	175.7	948	115	"
30/0600	18.3	176.4	940	120	"
30/1200	18.6	177.0	946	115	"
30/1800	18.9	177.6	952	110	"
31/0000	19.6	178.1	952	110	"

31/0600	20.3	178.5	956	105	"
31/1200	21.0	178.8	959	100	"
31/1800	21.6	179.2	959	100	"
01/0000	22.2	179.5	959	100	"
01/0600	22.8	179.6	959	100	"
01/1200	23.3	179.9	959	100	"
30/0600	**18.3**	**176.4**	**940**	**120**	**Maximum winds and minimum pressure**

Table 2. Number of hours in advance of formation of Kilo associated with the first CPHC 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
Low (<40%)	78
Medium (40%-60%)	72
High (>60%)	4

Table 3a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Kilo, 22 August – 1 September 2015. 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	30.6	49.2	62.1	66.8	**79.3**	**121.8**	170.4
OCD5	43.3	87.3	133.1	198.5	330.6	402.4	427.8
Forecasts	40	40	40	40	37	35	35
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 Hurricane Kilo, 22 August – 1 September 2015. 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 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (CPHC)	30.8	49.6	62.9	68.0	80.8	123.1	164.4
OCD5	44.2	89.1	135.0	200.9	332.2	399.6	405.5
GFSI	31.8	**47.6**	**57.5**	**60.0**	**66.3**	**85.7**	**109.2**
GHMI	35.2	53.5	**62.8**	68.7	98.2	153.2	214.6
HWFI	37.4	59.5	73.4	82.3	103.8	138.6	176.1
TVCE	31.3	**46.4**	**54.3**	**56.5**	**68.7**	**97.9**	**126.7**
AEMI	32.3	**48.3**	**60.6**	**64.5**	**75.0**	**97.0**	**118.1**
BAMS	49.3	89.3	124.6	150.4	191.7	231.0	253.1
BAMM	44.7	75.9	96.6	107.1	122.5	144.2	138.7
BAMD	44.6	76.8	100.5	114.0	147.2	215.6	260.8
Forecasts	39	39	39	39	36	34	32

Table 4a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Kilo, 22 August – 1 September 2015. 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	6.6	11.4	16.1	20.8	26.2	28.4	28.6
OCD5	6.6	11.1	15.2	16.6	49.8	55.9	48.5
Forecasts	40	40	40	40	37	35	35
OFCL (2010-14)	4.8	8.6	11.6	13.8	18.5	19.3	20.4

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Kilo, 22 August – 1 September 2015. 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 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	6.2	11.3	16.4	21.2	26.8	28.4	28.4
OCD5	**5.9**	**10.7**	**15.1**	**16.7**	49.2	56.0	48.6
HWFI	**5.4**	**11.0**	**15.5**	21.6	**26.0**	**23.3**	**24.8**
GHMI	9.3	15.8	18.3	25.6	34.1	34.6	36.4
DSHP	7.0	12.1	18.0	**21.1**	**24.9**	**26.4**	**26.6**
LGEM	6.5	11.3	16.4	**19.9**	**25.4**	30.4	31.6
IVCN	6.3	**10.8**	**15.1**	**19.7**	**23.6**	**25.1**	**25.5**
GFSI	5.3	**10.4**	**14.3**	**16.5**	**21.1**	**24.2**	**27.2**
Forecasts	39	39	39	39	36	34	34

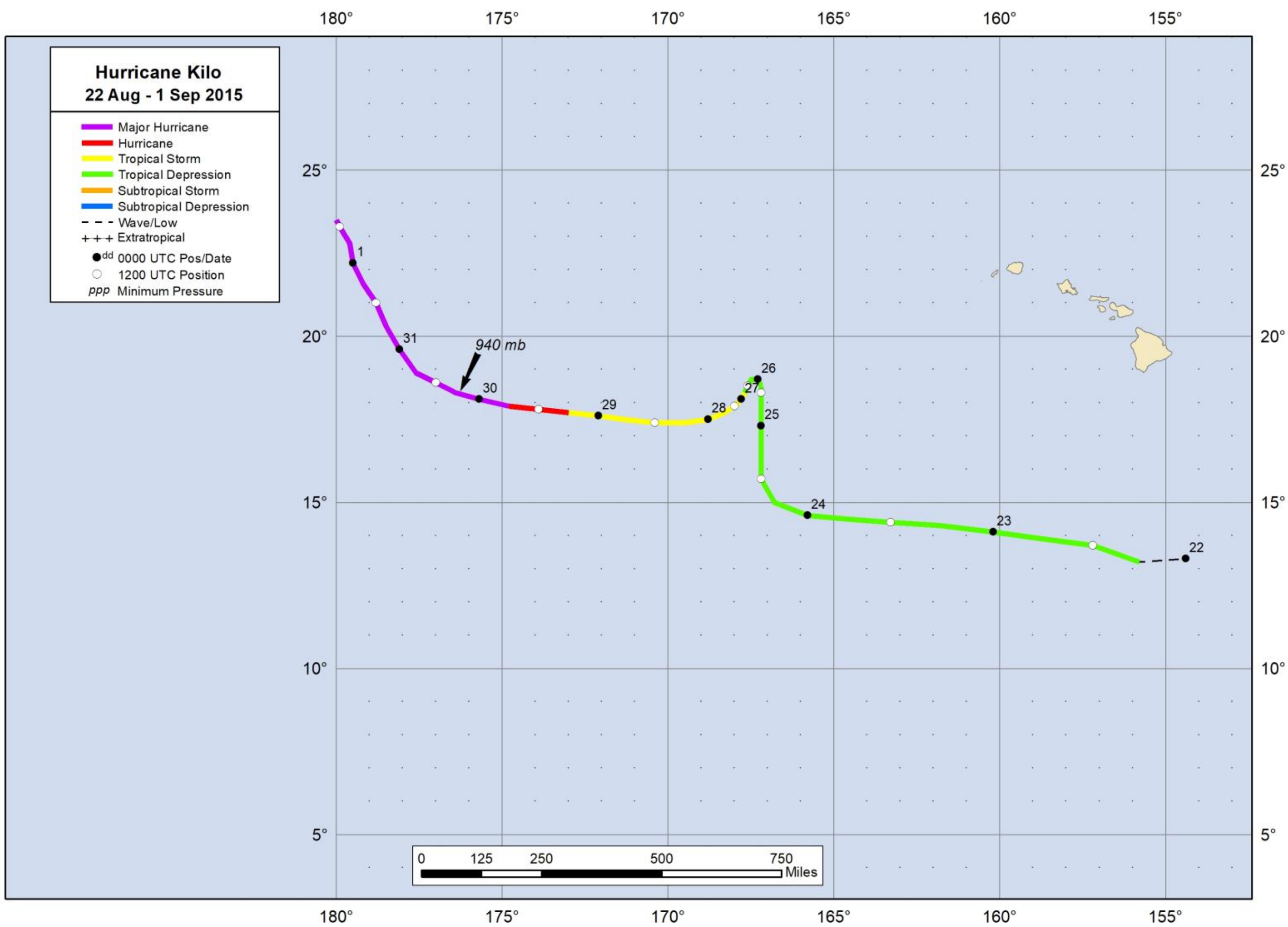

Figure 4. Best track positions and intensities for Hurricane Kilo, 22 August – 1 September 2015.