NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE MARIE

(EP132014)

22 – 28 August 2014

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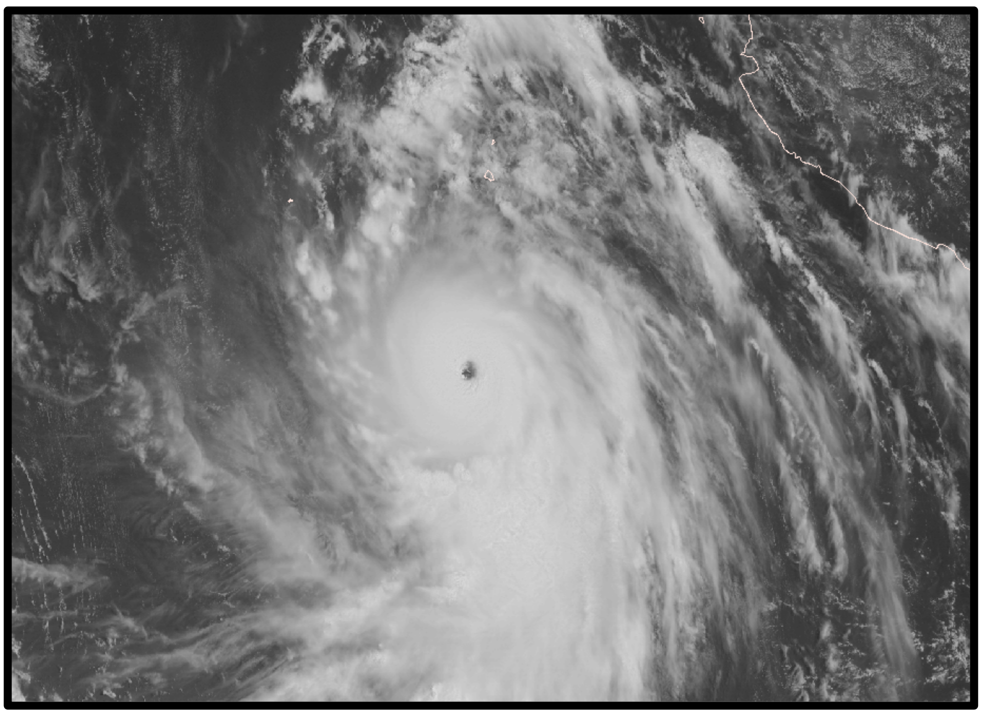

GOES-W VISIBLE IMAGE OF HURRICANE MARIE AT PEAK INTENSITY, 1800 UTC 24 AUGUST 2014. CREDIT: NHC

Marie was the first category 5 hurricane (on the Saffir-Simpson Hurricane Wind Scale) in the eastern North Pacific basin since Hurricane Celia in 2010. Its estimated maximum sustained winds of 140 kt make it tied for the fourth strongest hurricane in the eastern North Pacific since reliable records began in 1988. Although it remained well offshore, large waves from Marie affected portions of the coast from southwestern Mexico to southern California.

Hurricane Marie

22 – 28 AUGUST 2014

SYNOPTIC HISTORY

Hurricane Marie developed from a tropical wave that crossed the coast of Africa and entered the eastern tropical Atlantic on 10 August (Fig. 1). Although the wave was associated with a distinct low- to mid-level vorticity maximum and moist air near the wave axis, strong easterly shear and entrainment of dry environmental air prevented development of the system over the eastern and central tropical Atlantic. The wave entered the Caribbean Sea on 16 August, at which time interactions with South America and an upper-level trough further inhibited development. The wave crossed Central America around 19 August and subsequently moved into a far more conducive environment for development in the eastern North Pacific. The favorable environment supported persistent widespread convection that led to the development of a large but disorganized area of low pressure by early 20 August. Deep convection gradually became better organized during the next two days, resulting in the development of curved bands of showers and thunderstorms late on 21 August. A well-defined low-level circulation became apparent around 0000 UTC 22 August, marking the formation of a tropical depression centered about 320 n mi south-southeast of Acapulco, Mexico. The "best track" chart of the tropical cyclone's path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[1].

The newly formed depression remained embedded within a very favorable environment of low vertical wind shear, high moisture, and sea surface temperatures (SSTs) near 30°C. This led to a remarkable 66-h period of rapid intensification between 0000 UTC 22 August and 1800 UTC 24 August, during which the intensity increased by an estimated 110 kt. Marie strengthened by 60 kt during the final 24 h of this period, reaching an estimated peak intensity of 140 kt around 1800 UTC 24 August, while centered about 500 n mi south-southwest of Cabo San Lucas, Mexico. Marie was the first category 5 hurricane in the eastern North Pacific basin since Hurricane Celia in 2010.

Aside from a trochoidal wobble on 24 August, Marie moved on a fairly consistent west-northwestward to northwestward heading at about 12 to 14 kt throughout most of its duration as a tropical cyclone. After genesis, the cyclone was steered primarily by a large deep-layer ridge centered over the southern United States. As Marie moved around the periphery of the ridge, the ridge built westward over the southwestern United States and northern Mexico, resulting in a nearly constant steering flow through much of the tropical cyclone's existence.

An eyewall replacement that began on 24 August ended the rapid intensification and induced a steady weakening trend. Microwave imagery on 25 and 26 August (Fig. 5) show that

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[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.

the inner core of Marie featured concentric eyewalls, likely the primary factor in the weakening of the cyclone during that time. By late on 26 August, the eyewall began to open up in the northeast quadrant, indicative of further weakening. In addition, Marie began moving over a strong SST gradient, resulting in rapidly decreasing SSTs and a more stable thermodynamic environment. By 1800 UTC 27 August, Marie weakened to tropical storm intensity, and the inner core became devoid of deep convection shortly thereafter. Although shower activity persisted in bands over the southern portions of the circulation for another day, by 1800 UTC 29 August, the system lacked sufficient deep convection to be classified as a tropical cyclone. On 30 August the remnant low became embedded within weaker low-level easterly flow and slowed considerably while spinning down over the course of several days. A well-defined low-level center was no longer present after 0600 UTC 2 September.

METEOROLOGICAL STATISTICS

Observations in Marie (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 Tropical Rainfall Measuring Mission (TRMM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Marie.

Marie's estimated peak intensity of 140 kt is based on subjectively derived T-numbers of 7.0 from TAFB and SAB at 1800 UTC 24 August. A maximum objective ADT estimate of 7.1 and an AMSU intensity estimate of 143 kt within 6 h of 1800 UTC also support the peak intensity of 140 kt. Interestingly, Marie's estimated minimum pressure of 918 mb is tied for the lowest of the season with Hurricane Odile, which developed only 8 days after the dissipation of Marie.

In addition to its extreme intensity, Marie was a very large hurricane. At its largest, Marie's tropical-storm-force winds extended nearly 500 n mi across, with a maximum radial extent of 270 n mi in the northeastern quadrant. Mid- and high-level moisture advected northward by Marie also contributed to heavy rains, flooding, and mud slides in several Mexican states.

There were no ship reports of tropical-storm-force winds associated with Marie.

CASUALTY AND DAMAGE STATISTICS

Marie is believed to have caused four direct deaths[2]. Although Marie remained well offshore, large swells generated by the hurricane affected portions of the Mexican and southern California coastlines for several days. In Malibu, California, a surfer drowned in the high surf. In Mexico, a vessel with seven fishermen aboard capsized when it was hit by high waves near Cabo San Lucas. Although four of the fishermen were able to swim to shore, three went missing and are presumed to have drowned.

In the United States, damages totaled close to $20 million. Media reports indicated that nearly $16 million in damage occurred in and around the Port of Long Beach, where waves breached a major breakwater in multiple locations. Catalina Island was estimated to have sustained at least $3 million in damage. In addition, waves of 10 to 15 feet damaged boatyards and caused the shutdown of the Malibu Pier after several pilings were damaged.

FORECAST AND WARNING CRITIQUE

The formation of Marie was well forecast. Ninety-six hours prior to genesis, the Tropical Weather Outlook (TWO) stated that there was a "medium" chance of tropical cyclone formation to the south of Mexico, while the wave from which Marie developed was still located over the western Caribbean. The likelihood of tropical cyclone formation was increased to a "high" chance of formation in the five-day TWO 78 hours prior to the development of a tropical depression. Table 2 shows the number of hours in advance of formation that each likelihood category was first introduced into the TWO.

A verification of NHC official track forecasts for Marie is given in Table 3a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The relatively simple synoptic steering pattern and straight-line track of Marie contributed to the extremely low errors in the official track forecasts. Most of the guidance had similarly low errors, and the multi-model consensus, TVCN, was slightly better than the official track forecast at all forecast intervals. For example, although the average 48-h official track forecast error was a remarkably low 28 n mi, the TVCN error was a mere 26 n mi.

A verification of NHC official intensity forecasts for Marie is given in Table 4a. The mean official forecast intensity errors were generally comparable to the mean official errors for the previous 5-yr period except at 120 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. Although the first several official intensity

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[2] 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.

forecasts failed to capture the full magnitude of the rapid intensification of Marie (Fig. 6), these forecasts still captured the intensification better than most of the guidance, which failed to show the same increase in wind speeds. The official forecasts were aided by the SHIPS Rapid Intensification Index, which indicated probabilities as high as 64% of a 30-kt or greater increase in winds over 48 h during the first four forecast cycles. The official forecasts were generally too slow to weaken Marie after its peak intensity, while several models captured the timing and rate of the weakening fairly well. The combination of these two effects resulted in the official forecasts having lower errors than all of the guidance for the first 48 h, but higher errors for longer forecast intervals.

There were no watches or warnings associated with Marie.

Table 1. Best track for Hurricane Marie, 22-28 August 2014.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 0000	12.3	98.8	1007	30	tropical depression
22 / 0600	12.6	100.3	1006	35	tropical storm
22 / 1200	12.9	101.8	1002	45	"
22 / 1800	13.2	103.0	1000	50	"
23 / 0000	13.5	104.1	995	60	"
23 / 0600	13.9	105.1	992	65	hurricane
23 / 1200	14.3	106.1	983	75	"
23 / 1800	14.8	107.1	979	80	"
24 / 0000	15.5	108.2	971	90	"
24 / 0600	15.9	109.4	944	115	"
24 / 1200	16.0	110.8	929	130	"
24 / 1800	15.9	111.9	918	140	"
25 / 0000	16.3	112.5	922	135	"
25 / 0600	16.9	113.4	927	130	"
25 / 1200	17.5	114.3	932	125	"
25 / 1800	18.1	115.3	939	115	"
26 / 0000	18.8	116.2	952	100	"
26 / 0600	19.6	117.2	961	90	"
26 / 1200	20.4	118.4	965	85	"
26 / 1800	20.9	119.6	968	85	"
27 / 0000	21.2	120.8	971	80	"
27 / 0600	21.6	122.0	974	75	"
27 / 1200	22.1	123.2	980	65	"
27 / 1800	22.7	124.4	989	55	tropical storm
28 / 0000	23.4	125.8	992	50	"

28 / 0600	24.1	127.2	995	45	"
28 / 1200	24.8	128.5	997	40	"
28 / 1800	25.6	129.8	1000	35	low
29 / 0000	26.5	131.0	1001	35	"
29 / 0600	27.3	132.1	1002	35	"
29 / 1200	28.2	132.8	1002	30	"
29 / 1800	29.1	133.3	1003	30	"
30 / 0000	29.8	133.7	1004	25	"
30 / 0600	30.5	134.1	1005	25	"
30 / 1200	31.0	134.5	1005	25	"
30 / 1800	31.3	135.1	1006	25	"
31 / 0000	31.4	135.9	1007	25	"
31 / 0600	31.4	136.6	1008	25	"
31 / 1200	31.4	137.1	1009	25	"
31 / 1800	31.4	137.5	1010	25	"
01 / 0000	31.4	137.9	1011	25	"
01 / 0600	31.4	138.3	1011	25	"
01 / 1200	31.3	138.8	1011	25	"
01 / 1800	31.0	139.3	1011	25	"
02 / 0000	30.8	139.7	1011	25	"
02 / 0600	30.6	140.1	1012	25	"
02 / 1200					dissipated
24 / 1800	15.9	111.9	918	140	maximum winds and minimum pressure

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 (<30%)	66	-
Medium (30%-50%)	48	96
High (>50%)	24	78

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Marie, 22-28 August 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**17.7**	**23.5**	**24.4**	**35.4**	**69.7**	**96.9**	**134.0**
OCD5	38.7	73.9	91.9	109.2	163.8	212.2	296.4
Forecasts	25	23	21	19	15	11	7
OFCL (2009-13)	25.7	41.4	55.0	68.6	97.8	134.2	167.1
OCD5 (2009-13)	37.2	74.8	118.0	162.5	249.4	332.6	413.3

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Marie, 22-28 August 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	17.1	23.0	22.0	28.0	60.4	89.2	118.5
OCD5	37.8	74.4	93.9	116.7	180.7	236.7	344.7
GFSI	17.5	24.1	25.3	29.2	80.0	143.8	194.7
GHMI	19.9	34.4	54.1	80.1	118.1	162.7	180.6
HWFI	17.5	27.2	28.5	35.9	63.8	**77.9**	**88.5**
EGRI	22.0	31.6	36.2	40.0	**57.3**	**66.9**	**108.7**
EMXI	19.0	26.7	34.0	38.9	66.7	97.3	146.3
CMCI	24.6	38.3	55.5	77.6	130.2	155.4	177.4
NVGI	23.2	35.4	37.5	41.4	69.5	111.9	**99.6**
GFNI	30.9	53.5	63.7	84.2	126.2	139.6	**92.6**
AEMI	18.5	25.2	24.9	29.5	79.4	144.2	178.6
FSSE	**16.8**	**22.6**	28.4	36.1	67.1	121.7	183.4
TCON	**15.2**	**21.5**	**20.7**	**25.2**	**53.2**	**86.0**	**108.1**
TVCN	**15.1**	**21.3**	**21.9**	**26.4**	**53.5**	**85.2**	**115.5**
BAMS	33.1	58.1	85.8	107.6	121.9	137.6	189.1
BAMM	24.4	42.1	64.1	84.4	107.1	158.5	196.3
BAMD	25.6	45.4	61.8	74.7	71.7	120.4	201.0
Forecasts	22	20	18	16	12	8	4

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Marie, 22-28 August 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	7.2	12.6	**12.4**	**13.9**	19.3	16.4	22.9
OCD5	10.1	15.9	20.3	22.9	23.5	16.2	13.9
Forecasts	25	23	21	19	15	11	7
OFCL (2009-13)	6.1	10.4	13.4	14.5	15.0	16.4	16.1
OCD5 (2009-13)	7.7	12.7	16.4	18.8	20.5	20.3	20.8

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Marie, 22-28 August 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	7.3	12.7	12.3	13.6	16.8	17.0	24.2
OCD5	10.3	16.3	20.6	23.1	20.4	**14.4**	**12.8**
GFSI	11.9	20.7	26.9	31.5	28.9	19.9	**17.8**
GHMI	11.6	21.1	26.9	28.8	21.4	**13.9**	**9.2**
HWFI	9.7	16.0	21.6	22.4	**16.5**	**10.2**	**8.8**
EMXI	15.2	28.5	39.7	47.3	48.4	35.3	25.7
GFNI	10.2	17.4	21.6	23.0	**15.6**	**9.7**	**3.7**
FSSE	**7.2**	**11.0**	13.4	16.1	**13.0**	**7.9**	**13.2**
ICON	8.4	14.6	17.3	17.7	**10.8**	**7.3**	**11.8**
IVCN	8.4	14.6	17.3	17.7	**10.8**	**7.3**	**11.8**
DSHP	8.9	14.6	15.6	15.2	**15.9**	24.5	32.2
LGEM	8.2	14.5	17.1	18.7	**11.6**	**9.2**	**14.5**
Forecasts	24	22	20	18	14	10	6

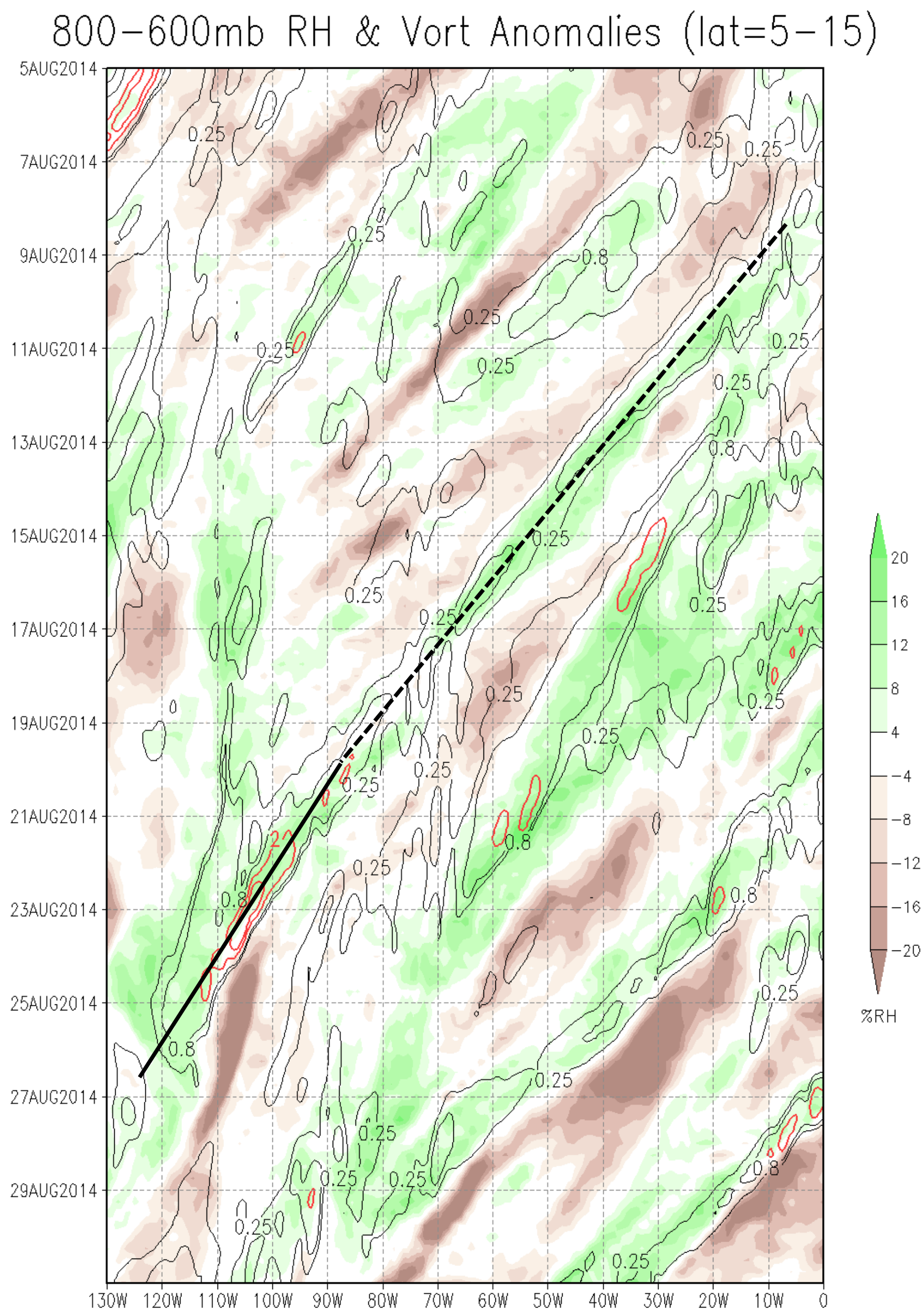

Figure 1. Time-longitude Hovmöller diagram of 600-800-mb layer-averaged relative humidity and vorticity anomalies from the mean for the period shown, averaged from 5°-15° N latitude, using analyses from the GFS model. The dashed line roughly corresponds to the axis of the wave from which Marie formed in the Atlantic, and the solid line represents the position of the wave and subsequent low in the Eastern Pacific.

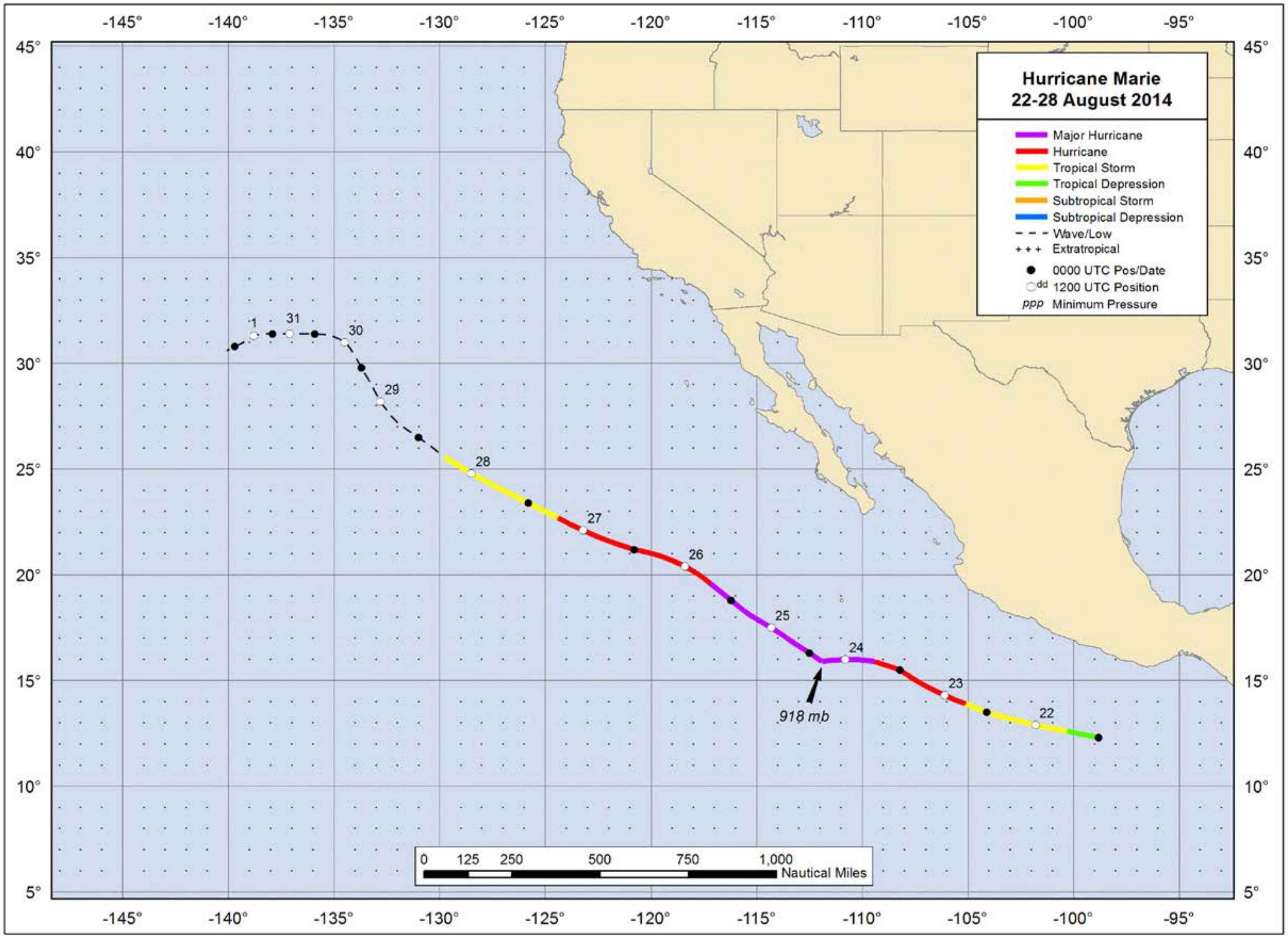

Figure 2. Best track positions for Hurricane Marie, 22-28 August 2014.

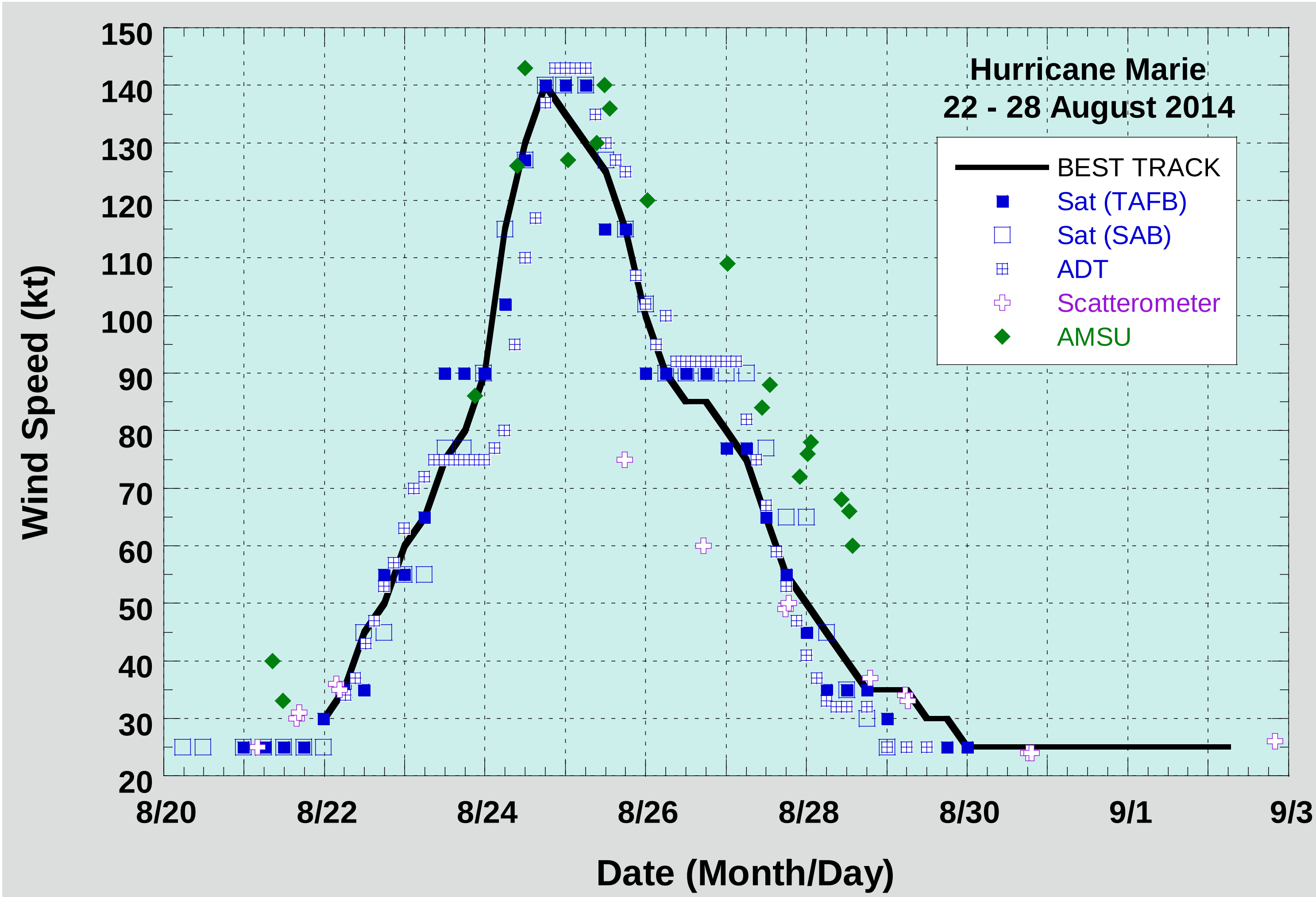

Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Marie, 22-28 August 2014. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

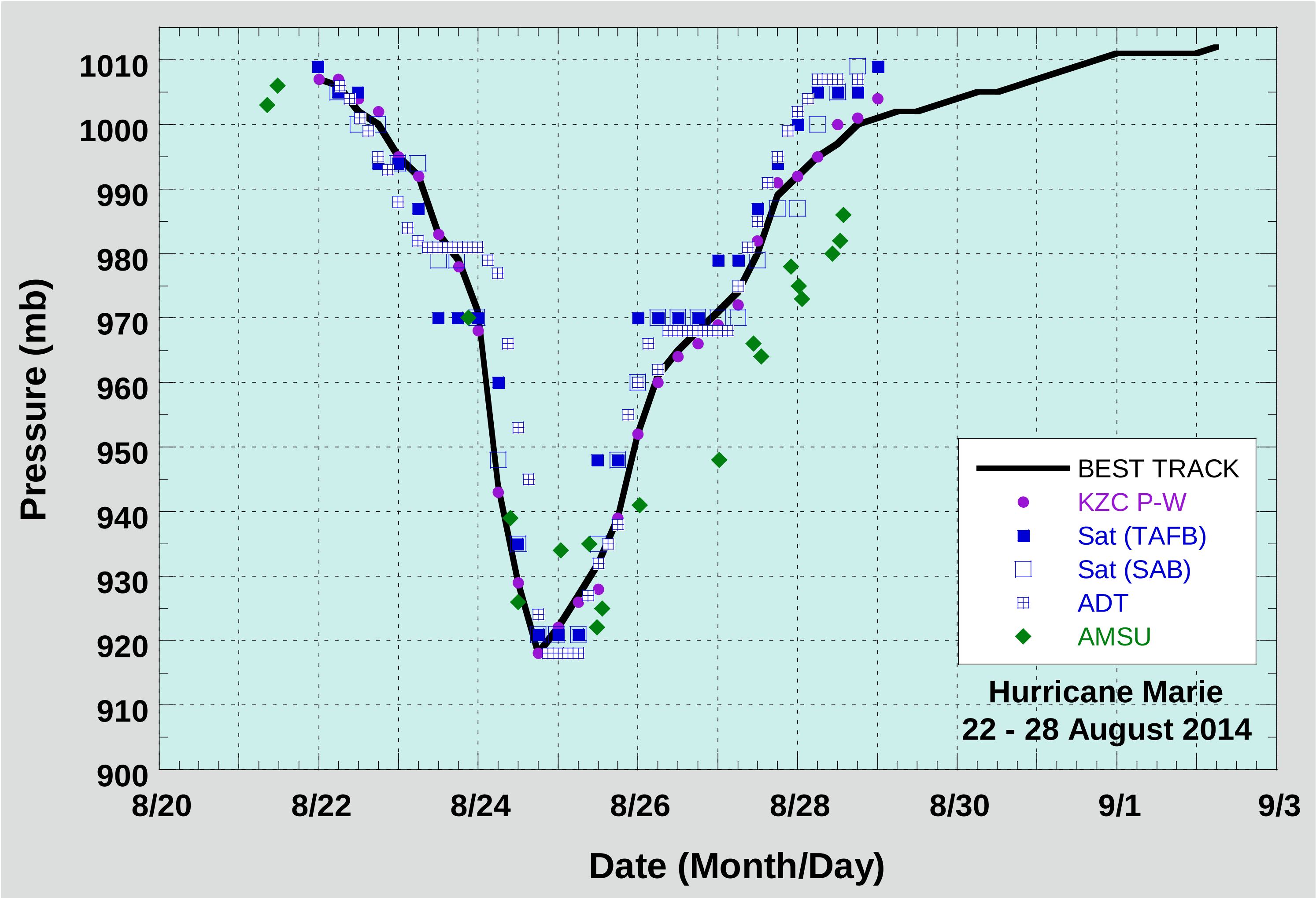

Figure 4. Selected pressure observations and best track minimum central pressure curve for Hurricane Marie, 22-28 August 2014. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.

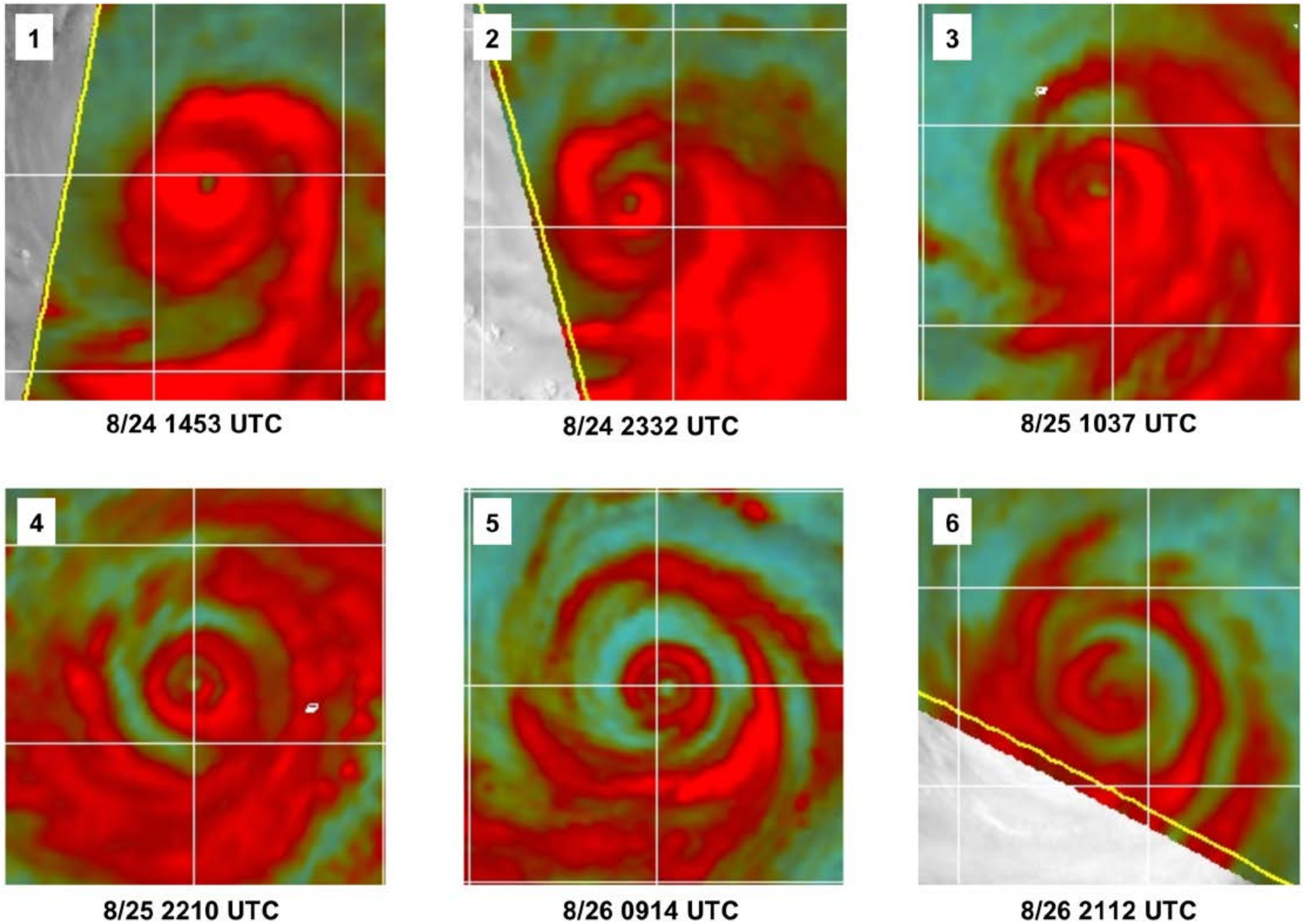

Figure 5. Microwave imagery of the inner core of Hurricane Marie from 24-26 August 2014. The images show the development of concentric eyewalls on 24 August that contributed to the weakening of Marie. Images courtesy of the Naval Research Laboratory.

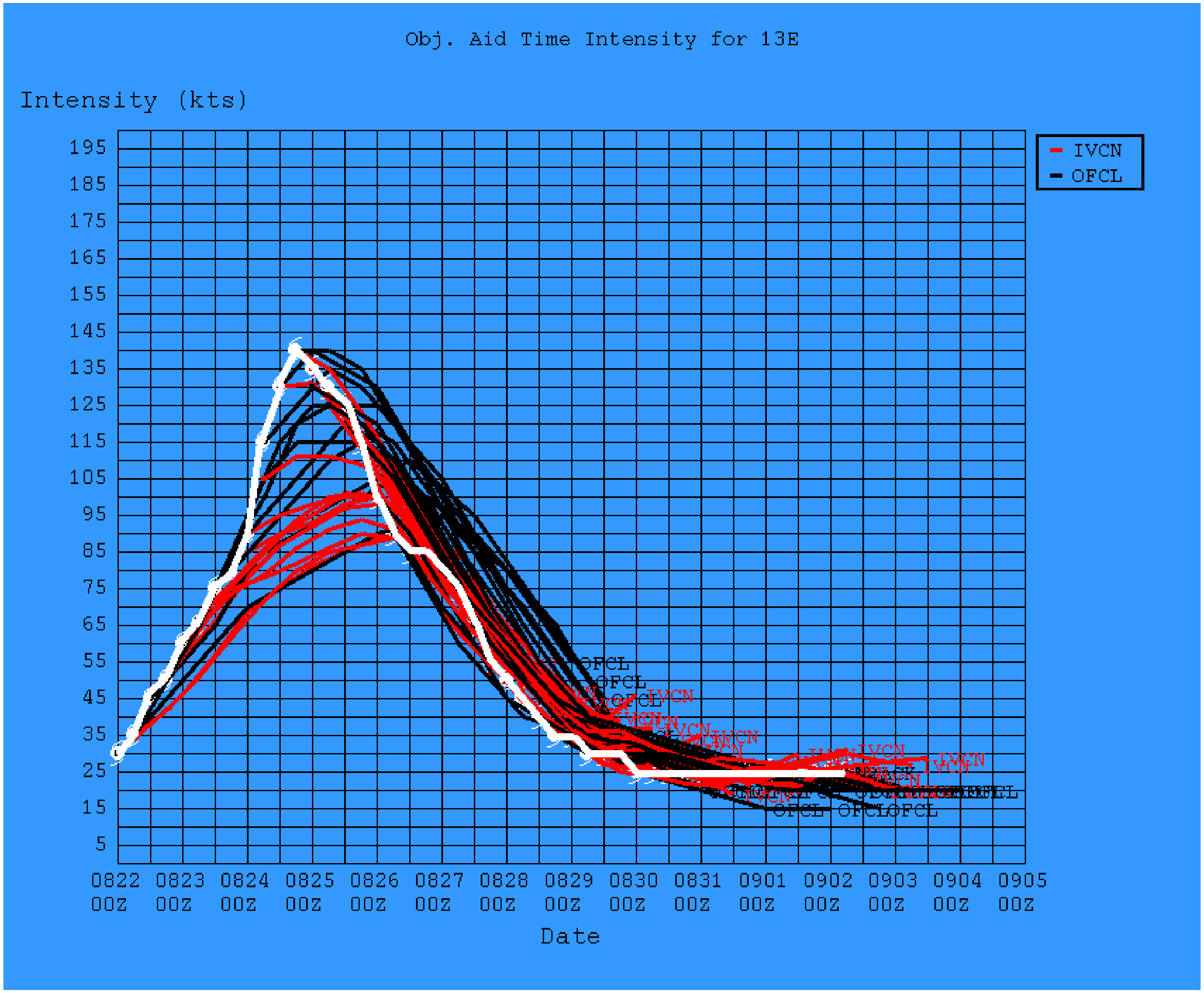

Figure 6. Selected official intensity forecasts (black lines) and multi-model consensus intensity forecasts (red lines) for Hurricane Marie, 22-28 August 2014. The best track is given by the thick white line with intensities given at 6-h intervals.