Tropical Cyclone Report
Hurricane Michael
(AL132012)
3-11 September 2012

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Michael was briefly a category 3 hurricane (on the Saffir-Simpson Hurricane Wind Scale) as it moved over the east-central Atlantic Ocean. Michael is only the fifth major hurricane in the satellite era to develop from a disturbance of non-tropical origin.

a. Synoptic History

Michael formed from a non-tropical weather system. A mid- to upper-level shortwave disturbance, originating from a longwave trough over eastern North America, cut off southwest of the Azores on 30 August and began to move slowly southwestward. The low-level reflection of this feature, a swirl of low clouds embedded within a weak trough, was first noted on 1 September about 500 n mi southwest of the Azores. Over the next day, sporadic convection caused the low-level swirl and trough to consolidate despite moderate northwesterly shear as it moved toward the southwest underneath a northeast-to-southwest oriented ridge. A small but well-defined low pressure area formed around 0000 UTC 2 September about 730 n mi southwest of the Azores. By 0600 UTC 3 September, the low pressure area attained enough persistent convective organization to be classified as a tropical depression. The "best track" chart of Michael's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

The forward speed of the depression decreased, and the heading turned, first toward the west and then toward the northwest, as the western extension of the ridge weakened ahead of a mid-latitude trough approaching from the west on 3 September. The approaching trough also caused the deep-layer vertical wind shear to shift to the southwest and lessen somewhat, allowing convection to develop closer to the center. Strengthening began shortly after the decrease in shear, and the system became a tropical storm at 0600 UTC 4 September about 1075 n mi southwest of the Azores. Michael entered a region of weak steering flow well ahead of the same trough, and the tropical storm slowed further before turning toward the northeast. Late on 4 September, the vertical wind shear decreased further, allowing the circulation to become vertically aligned. At the same time, microwave data confirmed the existence of a closed ring of shallow convection around the center. Strongly divergent upper-level flow over Michael associated with the upper-level trough helped to enhance the outflow of the tropical storm, and a period of rapid intensification (a 30 kt or greater intensity increase in a 24-h period) began around 1200 UTC 5 September (Fig. 4). During the next 24 h, the estimated intensity of Michael

[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.

increased by 50 kt as the cyclone accelerated toward the northeast ahead of the trough. The hurricane reached its peak intensity of 100 kt while centered about 890 n mi west-southwest of the Azores at 1200 UTC 6 September.

Shortly after reaching peak intensity, the small cyclone developed a concentric eyewall (Fig. 4), which resulted in an increase in the eye diameter and the beginning of period of weakening. In addition, the mid-latitude trough passed to the north of Michael later on 6 September, ending the favorable upper-level pattern. Michael began to experience northwesterly shear in the wake of the trough, which led to the erosion of convection in the northwest quadrant of the cyclone (Fig. 4) and additional weakening as the hurricane slowed down and turned back toward the northwest. As the mid-latitude trough continued to move away from the hurricane early on 8 September, the wind shear decreased, allowing deep convection to once again wrap around the center. Michael is estimated to have reached a secondary peak of 90 kt at 1800 UTC 8 September about 800 n mi west-southwest of the Azores. This second intensification phase was short-lived, however, as Michael was steered westward on 9 September, under the influence of a mid-level shortwave ridge that developed over the central Atlantic between Leslie and Michael. As Michael moved around the ridge, the outflow of Hurricane Leslie led to an increase in northerly vertical wind shear. In addition, dry air, originating from the subsident region behind the once helpful mid-latitude trough, wrapped around the center and was entrained into the inner core, helping to erode the deep convection.

As a result of these negative factors, the mid-level center of Michael became displaced to the south of the low-level center on 10 September. Michael weakened to a tropical storm around 0000 UTC 11 September as the low-level center became exposed and accelerated northward ahead of a deep-layer trough over the eastern United States. By 1200 UTC 11 September, the circulation was devoid of deep convection. Michael became a remnant low at 1800 UTC 11 September. The remnant low continued to accelerate to the northeast until it was absorbed by a front at 1200 UTC 12 September, about 820 n mi northwest of the Azores.

b. Meteorological Statistics

Observations in Michael (Figs. 1 and 2) 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 Michael.

The estimated peak intensity of 100 kt at 1200 UTC 6 September is based on a blend of subjective Dvorak classifications of T5.0/90 kt from TAFB and SAB, and a peak ADT CI estimate of T5.7/107 kt from UW-CIMSS. It is noted that there was some variability in both subjective and objective intensity estimates, depending on which satellite (GOES-13 or MET-9)

is used. The variability arises because of the differing viewing angles of the satellites. Michael is only the fifth Atlantic major hurricane of non-tropical origin in the satellite era. The four previous major hurricanes of non-tropical origin were Alicia (1983), Diana (1984), Bob (1991), and Claudette (1991).

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

c. Casualty and Damage Statistics

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

d. Forecast and Warning Critique

The genesis of Michael was poorly predicted. The system from which Michael originated was first introduced in the Tropical Weather Outlook 12 h prior to genesis and was assessed a low chance (less than 30%) of development. The probability of formation was increased to medium (30 to 50%) and then to a high chance (60% or greater) at the time of genesis and 12 h after genesis occurred, respectively. Because tropical cyclogenesis from an upper tropospheric cold low over the northeastern Atlantic basin is a rare occurrence and global models had little to no depiction of the feature which became Michael prior to genesis, tropical cyclone formation was not considered likely.

A verification of NHC official track forecasts for Michael is given in Table 2a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period at all forecast times. Official track errors were impressively low from 72-120 h, especially so at 120 h when errors were less than half of the 5-yr mean. Since OCD5 errors were higher than average during this period due to the complicated track of Michael, the very low track errors are particularly noteworthy. A homogeneous comparison of the official track errors with selected guidance models is given in Table 2b. The GFS (GFSI), multi-model consensus TVCA, and the Florida State Superensemble (FSSE) generally bested the official forecast through 48 h. Only the HWRF (HWFI), TVCA, and FSSE remained competitive with OFCL from 72-120 h.

A verification of NHC official intensity forecasts for Michael is given in Table 3a. Official forecast intensity errors were greater than the previous 5-yr period, except at 24 h. The higher than average errors resulted from early forecasts that did not anticipate the rapid intensification episode that Michael experienced a few days after genesis. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 3b. DSHP and LGEM were good performers relative to the official forecast through 48 h, as were, to a lesser degree, the intensity consensus aids ICON and IVCN. No guidance consistently outperformed the official forecast after 48 h.

There were no watches or warnings associated with Michael.

Table 1. Best track for Hurricane Michael, 3-11 September 2012.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
02 / 0000	28.9	36.7	1015	20	low
02 / 0600	28.1	37.9	1015	25	"
02 / 1200	27.2	39.2	1015	25	"
02 / 1800	26.4	40.1	1015	25	"
03 / 0000	25.8	40.7	1015	25	"
03 / 0600	25.4	41.2	1015	25	tropical depression
03 / 1200	25.3	41.7	1014	25	"
03 / 1800	25.5	42.1	1013	30	"
04 / 0000	25.8	42.5	1011	30	"
04 / 0600	26.2	43.0	1009	35	tropical storm
04 / 1200	26.7	43.5	1007	40	"
04 / 1800	27.1	43.7	1006	45	"
05 / 0000	27.4	43.8	1005	45	"
05 / 0600	27.8	43.8	1005	45	"
05 / 1200	28.2	43.5	1001	50	"
05 / 1800	28.6	43.1	992	65	hurricane
06 / 0000	29.0	42.6	981	80	"
06 / 0600	29.4	42.0	968	95	"
06 / 1200	29.9	41.4	964	100	"
06 / 1800	30.3	41.0	968	95	"
07 / 0000	30.6	40.8	970	90	"
07 / 0600	30.9	40.8	970	90	"
07 / 1200	31.1	41.0	970	90	"
07 / 1800	31.3	41.2	973	85	"
08 / 0000	31.6	41.5	977	80	"
08 / 0600	32.0	41.7	978	80	"
08 / 1200	32.4	41.9	975	85	"
08 / 1800	32.9	42.1	972	90	"
09 / 0000	33.3	42.3	973	90	"
09 / 0600	33.6	42.6	976	85	"
09 / 1200	33.7	42.9	976	85	"
09 / 1800	33.7	43.5	979	80	"
10 / 0000	33.6	44.1	982	75	"
10 / 0600	33.4	44.9	985	70	"
10 / 1200	33.6	45.8	986	70	"
10 / 1800	33.9	46.9	988	65	"
11 / 0000	34.8	47.8	991	60	tropical storm
11 / 0600	36.4	47.8	994	55	"
11 / 1200	38.2	47.6	997	45	"

11 / 1800	40.2	46.6	1000	40	Low
12 / 0000	42.5	45.0	1003	35	"
12 / 0600	45.0	42.6	1006	30	"
12 / 1200					dissipated
06 / 1200	29.9	41.4	964	100	maximum wind and minimum pressure

Table 2a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Michael. Mean errors for the 5-yr period 2007-11 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 (Michael)	**16.7**	**31.4**	**42.7**	**55.2**	**89.7**	**111.5**	**93.5**
OCD5 (Michael)	40.0	88.8	147.8	210.7	329.4	431.5	521.4
Forecasts	30	28	26	24	20	16	11
OFCL (2007-11)	30.4	48.4	65.9	83.1	124.4	166.5	213.4
OCD5 (2007-11)	46.9	95.2	151.7	211.6	316.8	404.3	485.2

Table 2b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Michael. 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 2a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	16.5	30.5	40.5	52.4	70.7	104.8	76.3
OCD5	42.8	96.1	159.6	226.2	356.3	520.4	626.3
GFSI	17.6	**30.0**	**34.7**	**41.0**	82.8	188.7	248.1
GHMI	18.1	33.6	47.0	61.3	88.4	117.7	201.1
HWFI	**16.0**	**29.6**	49.0	61.7	80.7	**85.1**	106.3
EMXI	16.8	33.0	52.0	69.1	99.6	124.3	149.7
CMCI	25.1	51.1	73.6	101.3	148.1	292.6	428.2
TVCA	**15.8**	**29.0**	**40.4**	**52.1**	73.1	**96.3**	89.8
FSSE	**13.4**	**25.8**	**39.0**	**49.2**	72.1	**100.5**	119.8
AEMI	18.9	34.0	49.7	58.5	78.1	177.3	240.0
LBAR	36.9	62.1	93.6	145.0	283.9	586.9	891.0
BAMS	34.9	62.3	81.9	100.4	95.9	219.7	275.3
BAMM	30.2	45.6	63.1	76.5	86.8	152.9	223.5
BAMD	25.9	38.9	54.6	58.1	110.7	147.9	182.0
Forecasts	25	23	21	19	15	10	6

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Michael. Mean errors for the 5-yr period 2007-11 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 (Michael)	7.5	**10.5**	15.4	19.4	19.5	21.9	21.8
OCD5 (Michael)	8.3	11.1	15.7	19.0	21.1	19.6	16.6
Forecasts	30	28	26	24	20	16	11
OFCL (2007-11)	7.1	10.8	13.0	15.0	16.9	17.1	18.1
OCD5 (2007-11)	8.4	12.4	15.4	17.7	20.5	21.5	21.2

Table 3b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Michael. 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	7.6	10.4	14.6	14.8	8.8	9.1	7.1
OCD5	8.6	11.8	16.4	17.2	17.2	16.7	11.0
GHMI	7.6	13.0	18.1	17.2	10.9	11.0	10.1
GHMI	9.2	12.9	17.0	18.5	14.9	15.2	15.1
DSHP	**7.2**	**9.6**	**12.3**	**12.4**	**7.1**	9.5	7.1
LGEM	7.9	**10.1**	**14.3**	**13.8**	9.6	9.7	**6.0**
ICON/IVCN[2]	7.6	10.4	**13.7**	**14.3**	9.1	**8.6**	7.3
FSSE	7.9	10.6	15.3	16.3	14.1	13.6	10.1
Forecasts	27	25	23	21	16	11	7

[2] ICON and IVCN are the same in this case since GFNI was not available.

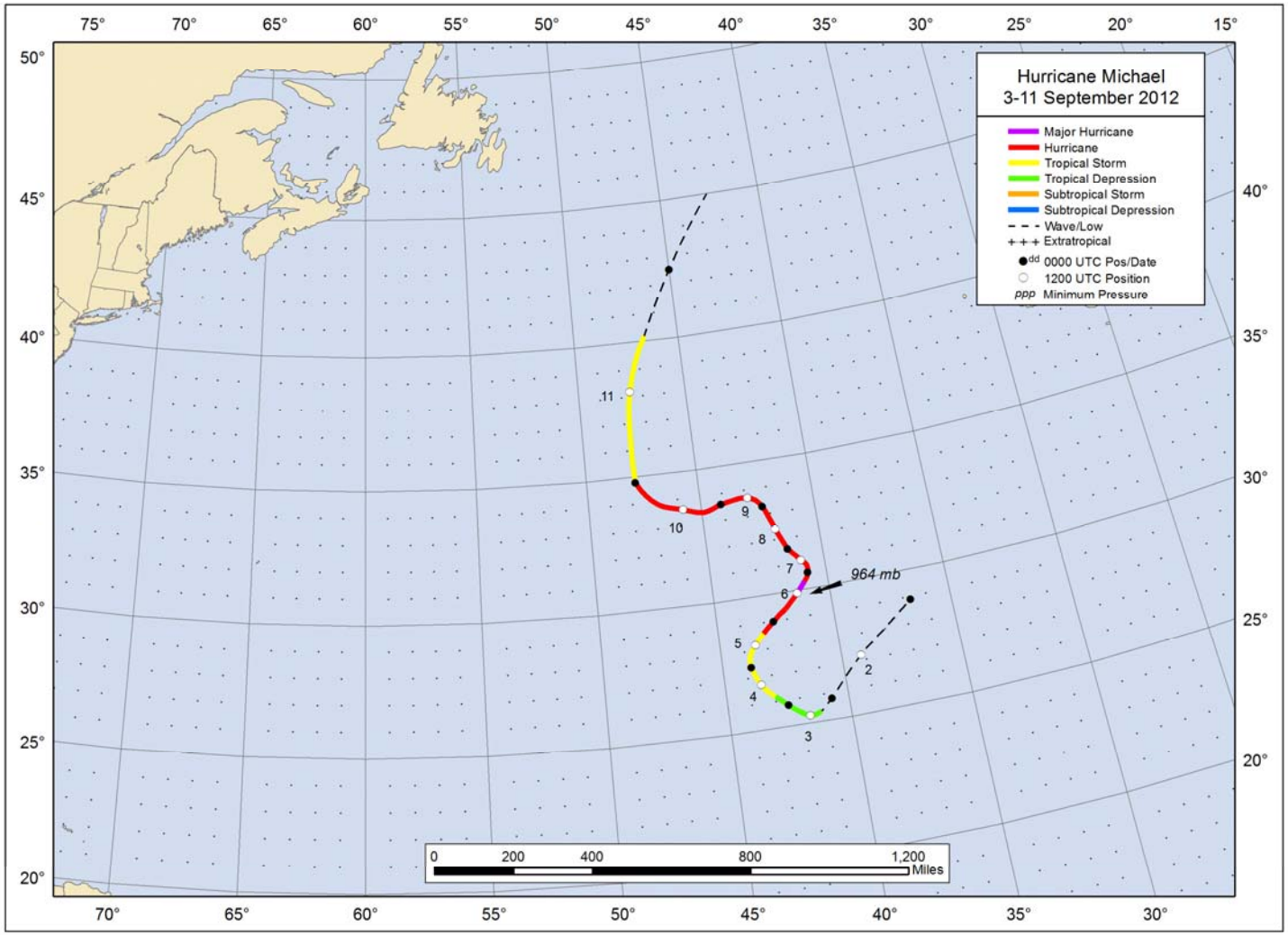

Figure 1. Best track positions for Hurricane Michael, 3-11 September 2012.

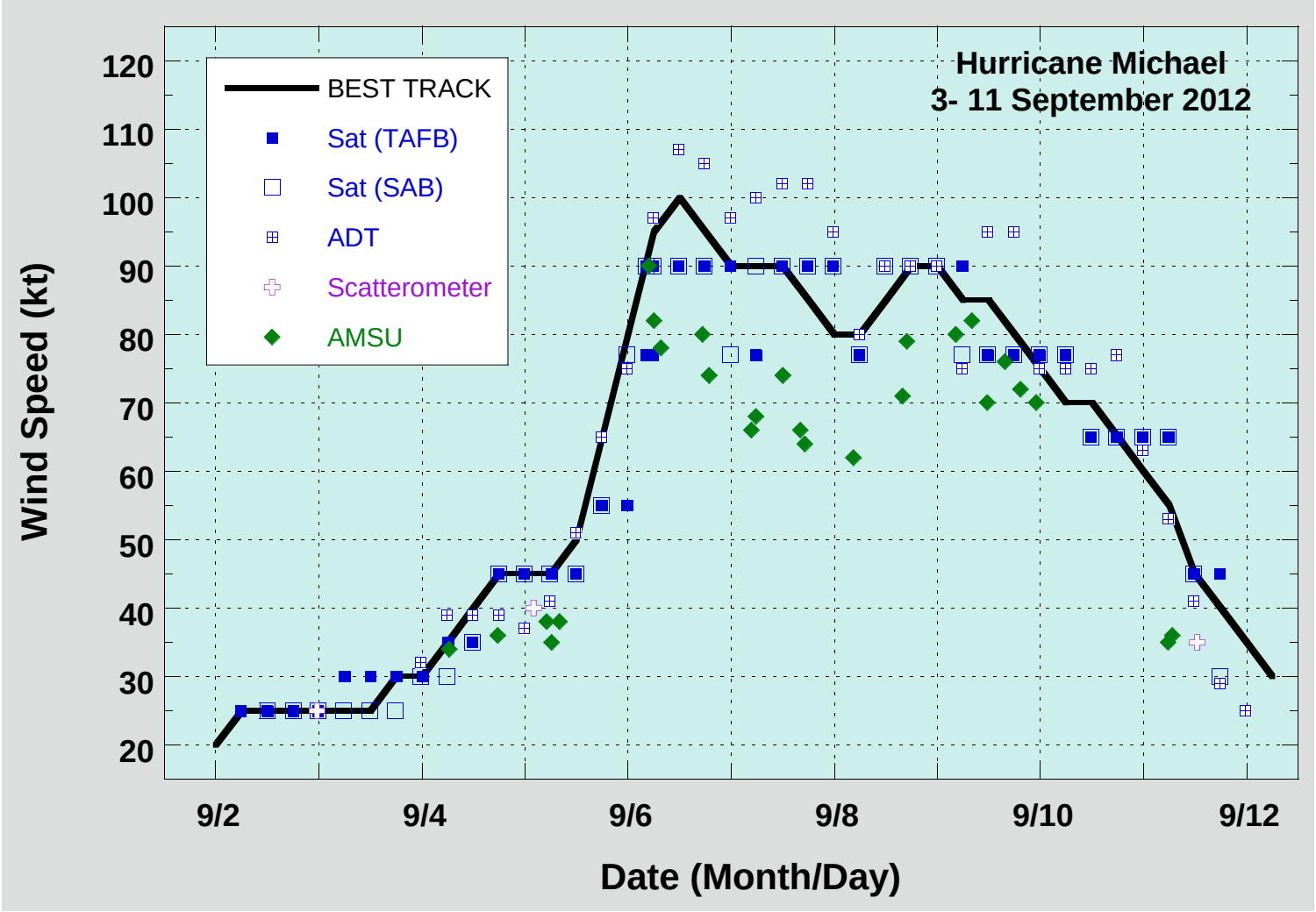

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Michael, 3-11 September 2012. Advanced Dvorak Technique estimates represent CI numbers. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC.

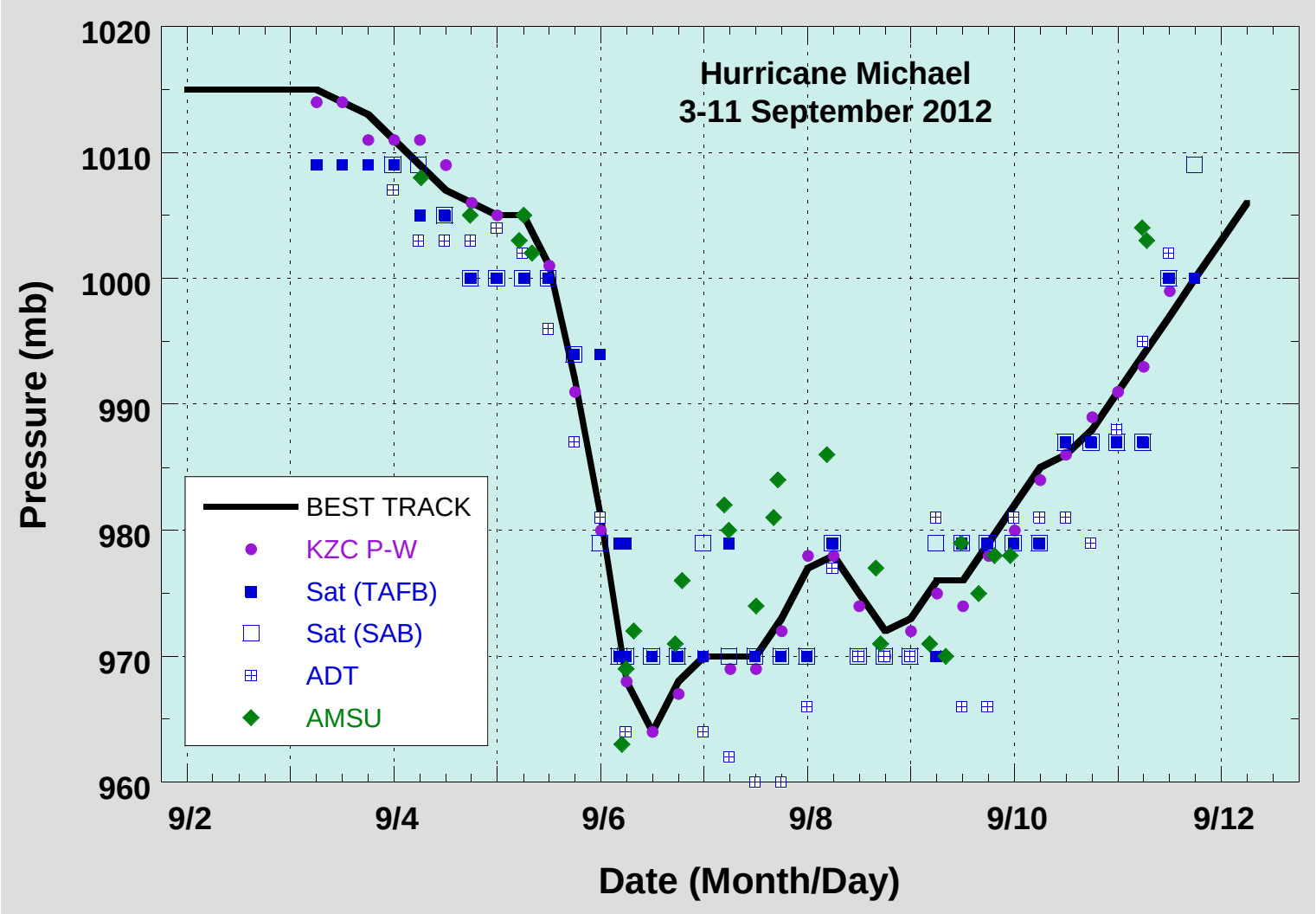

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Michael, 3-11 September 2012. Advanced Dvorak Technique estimates represent CI numbers. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. The KZC P-W values are obtained by applying the Knaff-Zehr-Courtney pressure-wind relationship to the best track wind data. Dashed vertical lines correspond to 0000 UTC.

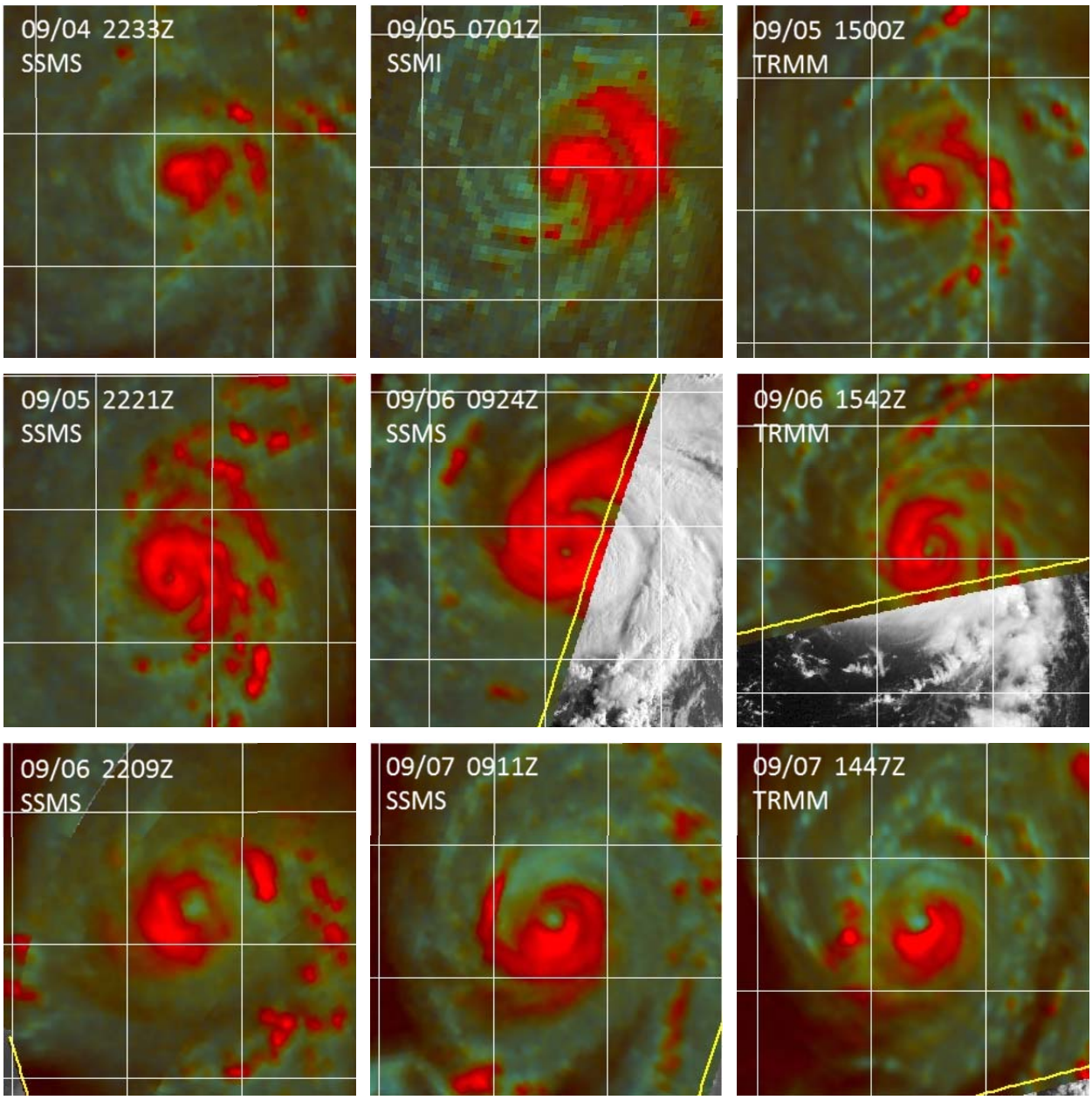

Figure 4. Microwave images from 4-6 September 2012, shown approximately every 8 h. 4 September (top row): gradual intensification and the development of an eye. 5 September (middle row): rapid intensification and the beginning of an eyewall replacement cycle (ERC), and 6 September (bottom row): completion of ERC and transition to a shear regime. Images courtesy of the Naval Research Lab (NRL) in Monterey, CA.