NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM MARIO

(EP142019)

17–22 September 2019

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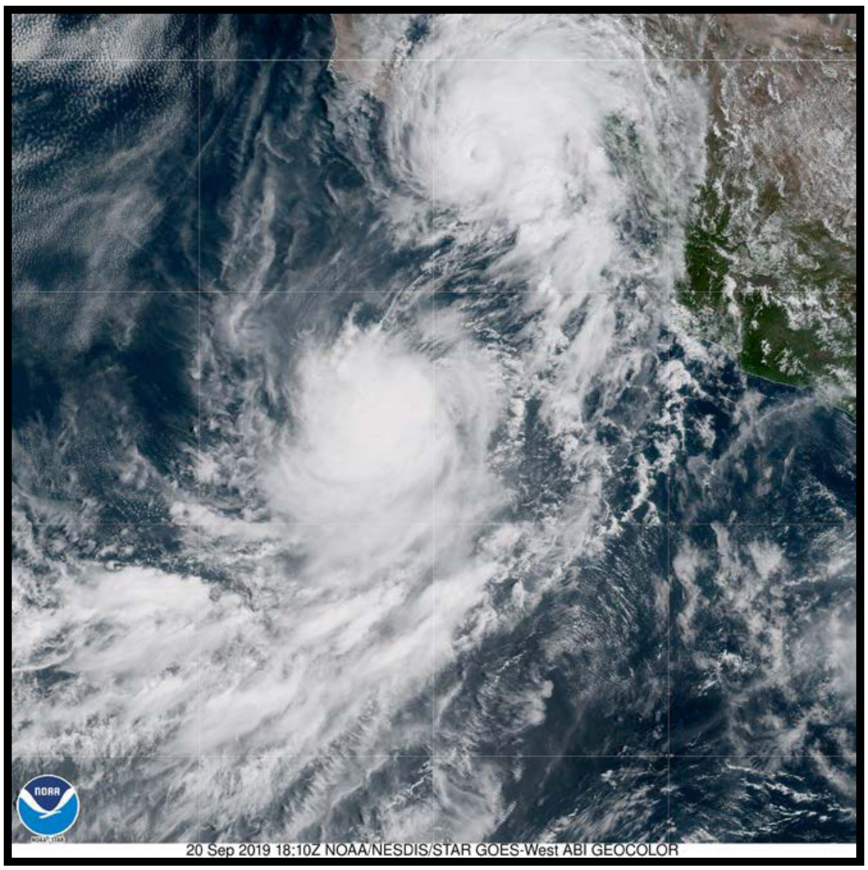

GOES-WEST GEOCOLOR VISIBLE IMAGE OF TROPICAL STORM MARIO (CENTER) AT 1810 UTC 20 SEPTEMBER 2019. HURRICANE LORENA IS IN THE UPPER PORTION OF THE IMAGE. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Mario moved northward as a tropical storm west of the coast of Mexico and dissipated west of the Baja California peninsula.

Tropical Storm Mario

17–22 SEPTEMBER 2019

SYNOPTIC HISTORY

Mario formed from a tropical wave that initially departed the west coast of Africa on 30 August—the same wave that spawned Tropical Storm Gabrielle over the eastern Atlantic on 3 September. After Gabrielle's genesis, the parent wave continued westward over the tropical Atlantic, reaching the Windward Islands on 9 September and then Central America by 12–13 September. The wave produced a large area of disorganized showers and thunderstorms once it moved over the eastern Pacific waters, and a low pressure system formed several hundred miles south-southwest of the southern coast of Mexico on 16 September. The associated convection became sufficiently organized for the system to become a tropical depression by 1200 UTC 17 September while centered about 500 n mi south-southwest of Manzanillo, Mexico. The depression strengthened into a tropical storm 12 h later while located about 450 n mi southwest of Manzanillo. The "best track" chart of Mario'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].

When it became a tropical storm, Mario was located only about 430 n mi west-southwest of strengthening Tropical Storm Lorena. Ridging to the north of Mario and Lorena was being eroded by a deep-layer trough digging along the west coast of the United States, and this caused both storms to move generally northwestward in tandem for a couple of days. Moderate east-northeasterly shear from Lorena's upper-level outflow disrupted Mario's structure a bit, yet the cyclone was able to strengthen over warm waters of about 29°C to an estimated peak intensity of 60 kt by 1800 UTC 18 September. With no abatement of the shear, Mario weakened slightly early the next day and maintained a steady intensity for about 2 days while it turned northward and northeastward and slowed down significantly in the wake of Lorena.

By late on 20 September, deep-layer shear increased further over Mario, causing most of the storm's deep convection to be sheared southwest of the center early on 21 September, beginning the cyclone's weakening trend. Another round of deep convection formed near the center before sunrise that day, but that activity also sheared away from the center by late morning. Mario moved northward to north-northwestward at a faster speed nearly convection-less for over 18 h and weakened to a tropical depression around 0600 UTC 22 September about 140 n mi south-southwest of the southern tip of the Baja California peninsula. One final burst of convection formed later that morning, but Mario degenerated into a remnant low by 0000 UTC 23 September. The remnant low slowed down, turning northward and then eastward as it approached the Baja

[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.

California peninsula, but it ultimately dissipated soon after 1800 UTC 24 September about 50 n mi south-southwest of Punta Abreojos, Baja California Sur.

METEOROLOGICAL STATISTICS

Observations in Mario (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), subjective Dvorak technique estimates from the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) 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 Mario.

Mario's estimated peak intensity of 60 kt occurred from 1800 UTC 18 September through 0000 UTC 19 September. This peak intensity has greater-than-normal uncertainty since intensity estimates ranged from 45 kt (from TAFB) to 70 kt (from the UW-CIMSS ADT) around that time period. The 60-kt intensity is a blend of the various intensity estimates, and since Mario was a small storm at the time, the intensity is just a little higher than the maximum winds indicated by an ASCAT pass late on 18 September to account for instrument resolution. The estimated minimum central pressure of 991 mb is based on the Knaff-Zehr-Courtney pressure wind relationship. Mario's lowest central pressure occurred after the time of its peak intensity as a result of the storm subsequently moving into an environment of lower ambient pressures as it got closer to Hurricane Lorena, growing in size, slowing down, and moving to a higher latitude—all factors that contribute to a lower central pressure.

There were no ship reports of winds of tropical storm force in association with Mario. Mario's center passed about 35–40 n mi east of Socorro Island, and a Mexican Navy automatic station on the island reported a maximum sustained wind of 32 kt and a gust to 41 kt between 1500 and 1515 UTC 21 September. The station reported a minimum pressure of 994.4 mb at 1245 UTC that day, although its pressure tends to run about 4–5 mb too low.

CASUALTY AND DAMAGE STATISTICS

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

FORECAST AND WARNING CRITIQUE

Mario's genesis was forecast fairly well. Table 2 provides the number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. The incipient tropical wave was first introduced in the TWO and given a low (<40%) chance of genesis during the next 2 and 5 days 114 h (4.75 days) before tropical cyclone formation occurred. The 5-day chance of genesis was raised to the medium (40–60%) and high

(>60%) categories 84 h (3.5 days) and 24 h (1 day) before formation, respectively. The 2-day chance of genesis was raised to the medium and high categories 30 h and 18 h before formation, respectively.

A verification of NHC official track forecasts for Mario is given in Table 3a. Official forecast track errors were much larger than the mean official errors for the previous 5-yr period at all time periods. The official errors were two to three times higher than the 5-yr errors from 36–120 h. Climatology and persistence model (OCD5) errors were also larger than their respective 5-yr means, suggesting that Mario's track was more difficult than normal to forecast. However, the OCD5 errors did not deviate from their 5-yr means by as large of a factor as did the official forecasts from their 5-yr means. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. A few models, in particular the UKMET (EGRI) and COAMPS-TC (CTCI) did not consistently maintain Mario as a distinct system separate from Lorena, and thus did not provide enough forecasts for the homogeneous verification. Even though the NHC forecast track errors were large, they were still generally lower than the individual deterministic global and regional track models. On the other hand, the simple consensus aids and the corrected-consensus aids all generally performed better than the official forecasts, with several having lower errors at all forecast times for which the homogeneous sample was verified (12–96 h). Interestingly, the primitive Medium-Layer Trajectory and Beta Model (TABM) also performed quite well, having lower errors than the official forecasts from 24–96 h.

The difficulty in Mario's track predictions largely stemmed from uncertainty in how much the storm would interact with Hurricane Lorena to its northeast. Model forecasts at the time of Mario's genesis initially depicted little interaction between Mario and Lorena, indicating that Mario would move northwestward and then westward during the ensuing five days (Fig. 4a). Instead, Lorena had a notable influence and caused Mario to move generally northward toward the Baja California peninsula, ending up significantly farther northeast of the initial model solutions five days after its genesis. NHC's official track forecasts gradually shifted northeastward as the interaction between the two cyclones became more certain, yet those forecasts—and the models that they were predicated on—had a clear westward bias for much of Mario's existence (Fig. 4b).

A verification of NHC official intensity forecasts for Mario is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period through 72 h and much higher at 96 and 120 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official intensity forecasts were not very good compared to model guidance, with the dynamical models and consensus aids having lower intensity errors than the NHC forecasts at most forecast times. The statistical-dynamical SHIPS and LGEM models performed less well and overall had larger errors compared to the official forecasts. Because it was initially assumed that Mario would not be adversely affected by shear from Lorena's upper-level outflow, the initial forecasts showed Mario strengthening more than it did, and thus NHC's predictions had a high bias.

There were no coastal watches or warnings issued in association with Mario.

Table 1. Best track for Tropical Storm Mario, 17–22 September 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
16 / 1200	9.9	107.0	1009	25	low
16 / 1800	10.0	107.3	1008	30	"
17 / 0000	10.3	107.6	1008	30	"
17 / 0600	10.8	107.9	1007	30	"
17 / 1200	11.5	108.1	1006	30	tropical depression
17 / 1800	12.2	108.4	1005	30	"
18 / 0000	12.9	108.9	1004	35	tropical storm
18 / 0600	13.5	109.7	1001	45	"
18 / 1200	14.0	110.6	998	55	"
18 / 1800	14.4	111.4	996	60	"
19 / 0000	15.0	111.8	995	60	"
19 / 0600	15.7	111.8	995	55	"
19 / 1200	16.2	111.5	995	55	"
19 / 1800	16.6	111.1	995	55	"
20 / 0000	17.0	110.7	994	55	"
20 / 0600	17.3	110.4	993	55	"
20 / 1200	17.6	110.1	992	55	"
20 / 1800	17.8	110.0	991	55	"
21 / 0000	18.1	110.1	991	55	"
21 / 0600	18.4	110.2	995	50	"
21 / 1200	18.8	110.3	998	45	"
21 / 1800	19.3	110.4	1002	40	"
22 / 0000	20.0	110.6	1004	35	"
22 / 0600	20.7	111.0	1005	30	tropical depression
22 / 1200	21.5	111.5	1006	30	"
22 / 1800	22.3	112.1	1006	30	"
23 / 0000	23.1	112.7	1006	30	low
23 / 0600	23.9	113.3	1007	25	"
23 / 1200	24.6	114.0	1007	25	"
23 / 1800	25.1	114.5	1007	25	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
24 / 0000	25.7	114.6	1008	20	"
24 / 0600	25.9	114.4	1008	20	"
24 / 1200	26.0	114.1	1009	20	"
24 / 1800	26.0	113.9	1009	20	"
25 / 0000					dissipated
18 / 1800	14.4	111.4	996	60	maximum winds
20 / 1800	17.8	110.0	991	55	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 (<40%)	114	114
Medium (40%-60%)	30	84
High (>60%)	18	24

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Mario, 17–22 September 2019. 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	27.1	50.7	82.2	126.1	177.3	236.7	375.3
OCD5	48.2	97.3	145.3	198.7	317.2	411.0	375.1
Forecasts	20	18	16	14	10	6	2
OFCL (2014-18)	21.1	32.2	41.8	51.8	75.7	101.1	133.7
OCD5 (2014-18)	34.0	69.7	109.0	148.4	223.5	285.5	356.7

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Mario, 17–22 September 2019. 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	30.7	55.4	83.4	128.0	167.7	215.3	
OCD5	48.4	101.5	159.8	234.0	360.3	496.1	
GFSI	34.3	**54.3**	**81.9**	151.5	207.8	230.6	
EMXI	**30.1**	57.4	**78.9**	**116.2**	189.4	227.8	
NVGI	43.7	90.3	144.8	201.0	302.5	313.3	
HWFI	40.0	74.2	106.3	140.5	**130.9**	**127.8**	
HMNI	37.7	67.6	102.0	153.2	**154.1**	**162.0**	
AEMI	36.7	68.3	90.7	130.1	**160.4**	**186.6**	
TVCE	**30.3**	**54.7**	**81.0**	**124.1**	**159.7**	**165.4**	
TVCX	**29.0**	**53.0**	**76.0**	**116.6**	**162.0**	**193.0**	
TVDG	**30.4**	**50.4**	**76.6**	**118.1**	174.3	**203.5**	
GFEX	31.2	**50.6**	**67.4**	**108.0**	176.4	221.7	
HCCA	**29.1**	**47.4**	**68.6**	**105.8**	**134.0**	**166.0**	
FSSE	**30.2**	**53.4**	**79.7**	**116.0**	**160.4**	**151.7**	
TABS	36.8	66.3	99.5	142.4	209.8	265.5	
TABM	32.4	**51.2**	**65.2**	**81.8**	**106.3**	**108.2**	
TABD	42.2	90.0	139.2	179.6	253.1	345.2	
Forecasts	13	12	11	9	6	3	

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Mario, 17–22 September 2019. 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	**5.2**	**8.1**	**7.5**	**10.0**	**14.0**	28.3	30.0
OCD5	4.8	9.6	11.7	12.2	17.4	23.2	26.5
Forecasts	20	18	16	14	10	6	2
OFCL (2014-18)	6.1	10.0	12.2	13.7	15.5	15.4	15.7
OCD5 (2014-18)	7.9	13.1	16.7	19.2	21.8	22.9	22.1

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Mario, 17–22 September 2019. 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	5.0	7.2	6.2	10.0	13.0	27.5	
OCD5	**4.5**	9.1	9.8	12.1	19.4	**24.5**	
DSHP	**4.6**	7.7	11.8	16.7	22.8	**24.5**	
LGEM	**4.3**	**7.0**	7.8	11.3	15.6	**18.5**	
HWFI	6.4	**6.8**	**4.0**	**6.0**	**9.2**	**16.0**	
HMNI	**4.3**	**6.0**	7.9	**8.4**	**11.2**	**13.5**	
CTCI	**3.9**	**3.8**	7.6	**9.7**	**9.8**	**5.5**	
ICON	**3.9**	**4.7**	**5.5**	**8.0**	**8.8**	**11.5**	
IVCN	**3.5**	**4.1**	**4.1**	**5.4**	**5.8**	**8.5**	
IVDR	**3.6**	**3.8**	**3.6**	**4.7**	**4.2**	**7.0**	
HCCA	**3.8**	**6.6**	7.8	**8.3**	**3.6**	**13.0**	
FSSE	**3.2**	**5.3**	7.8	10.6	**11.6**	**21.0**	
GFSI	5.0	7.2	8.4	10.7	**11.6**	**16.0**	
EMXI	**4.6**	**7.0**	8.4	**8.1**	**8.4**	**6.0**	
Forecasts	10	9	8	7	5	2	

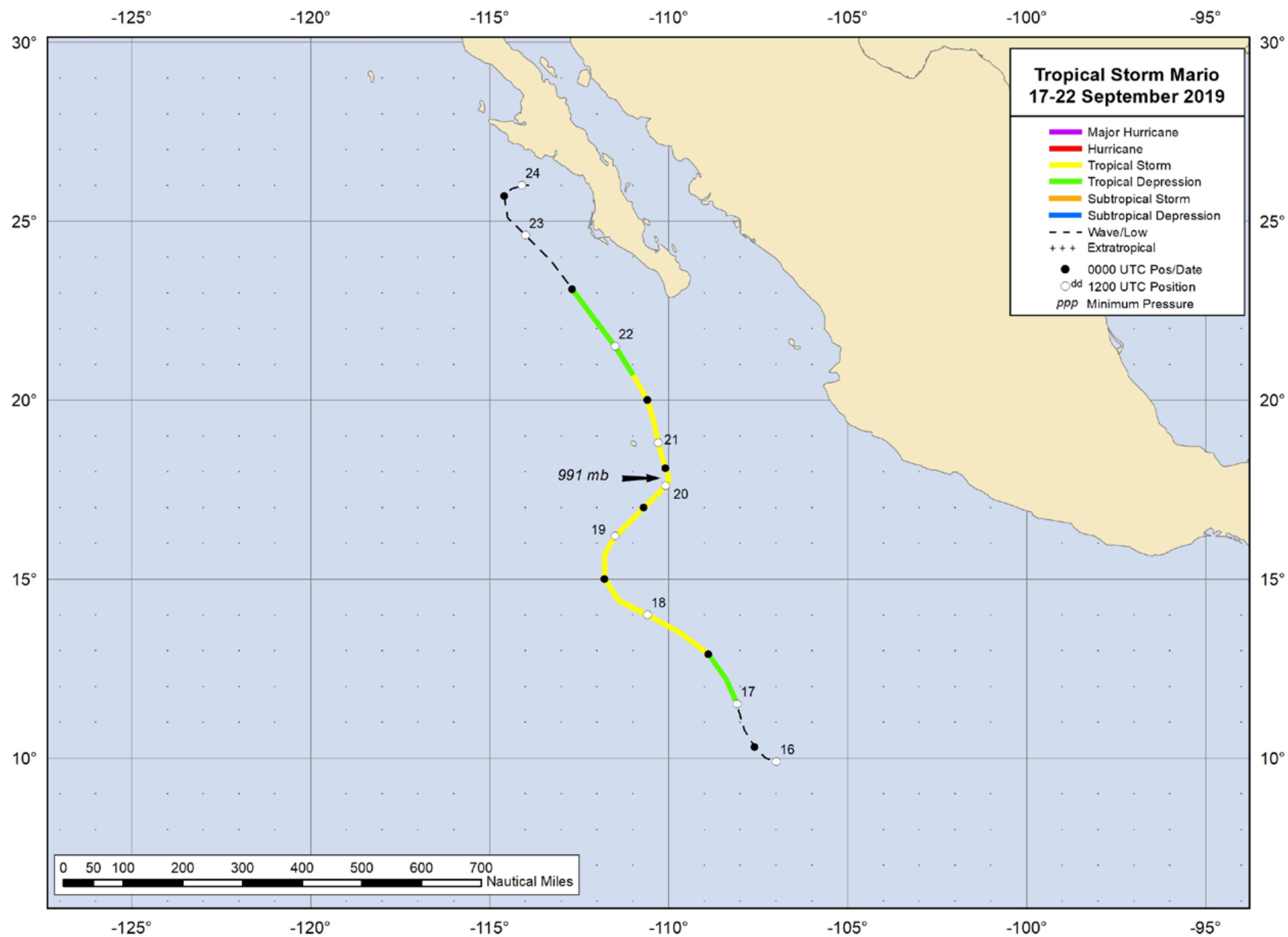

Figure 1. Best track positions for Tropical Storm Mario, 17–22 September 2019.

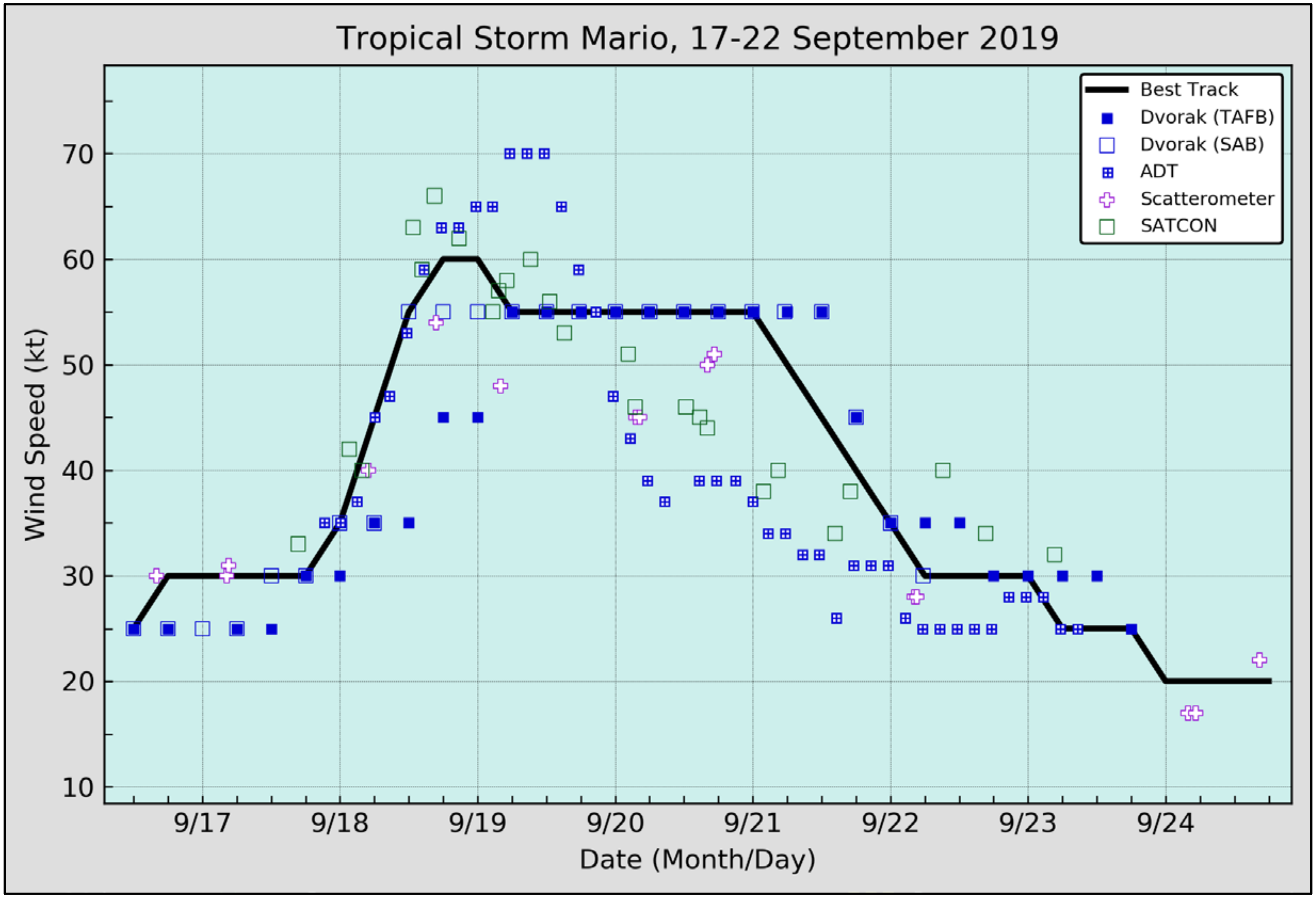

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Mario, 17–22 September 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

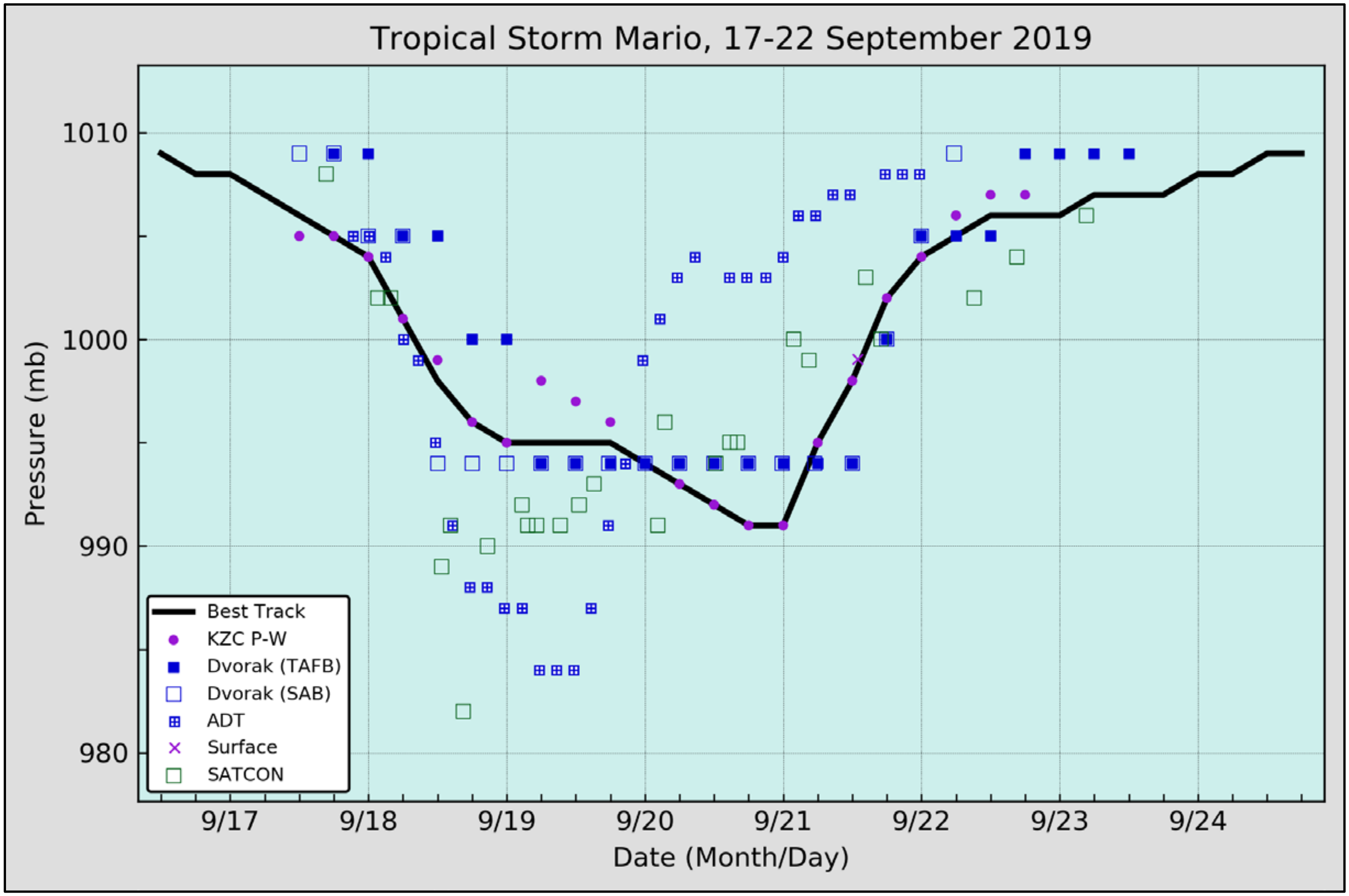

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Mario, 17–22 September 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.

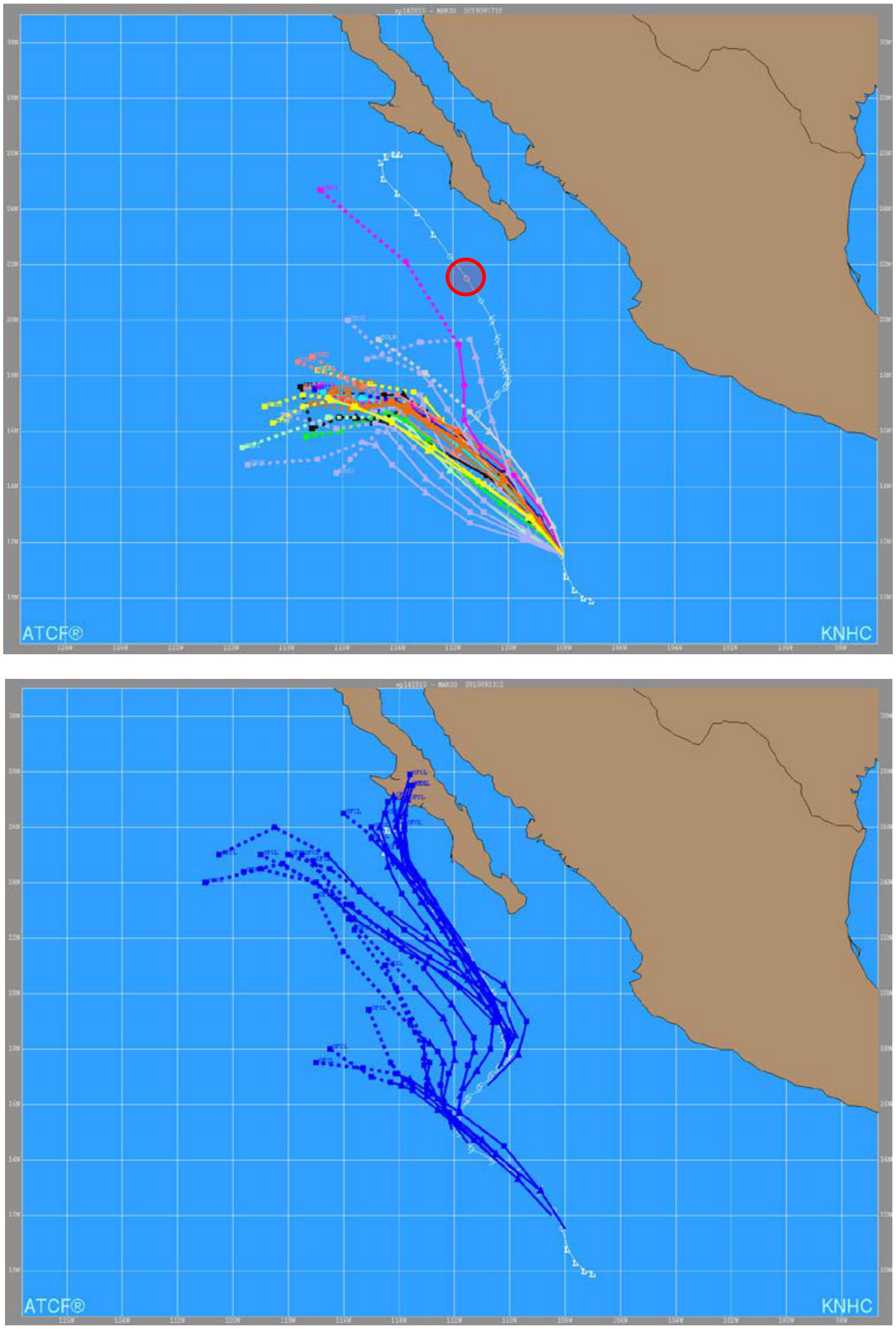

Figure 4. (a) Five-day track models for Tropical Storm Mario from the 1200 UTC 17 September forecast cycle. (b) All NHC official five-day track forecasts for Mario from 1200 UTC 17 September through 1200 UTC 23 September. Mario's best track is indicated by the white line and symbols, with the red circle in (a) denoting the storm's location five days after its genesis.