

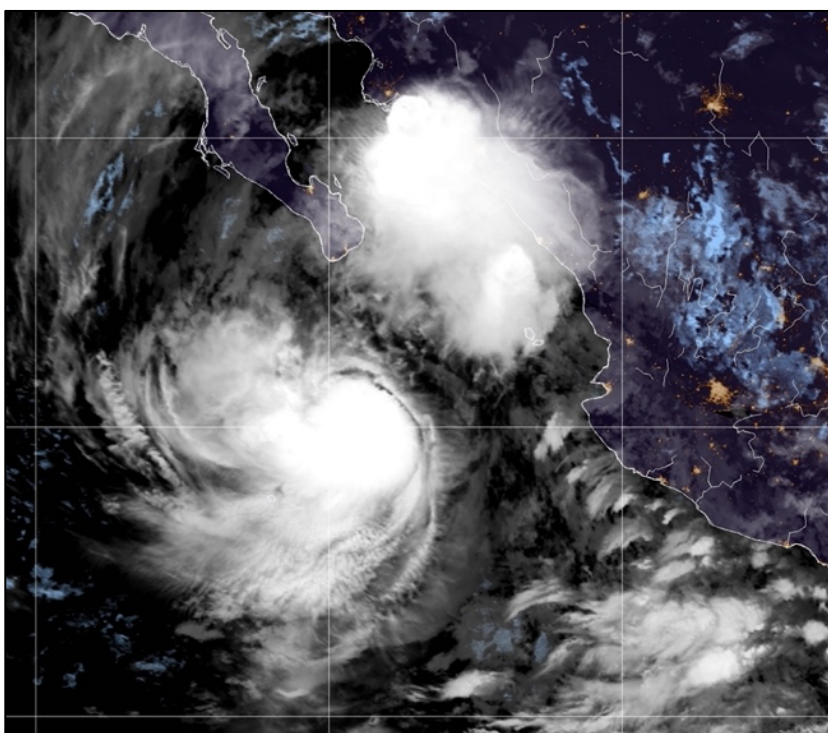


NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM MADELINE (EP142022)

16–20 September 2022

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National Hurricane Center
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GOES-16 GEOCOLOR IMAGE OF TROPICAL STORM MADELINE AT 1200 UTC 19 SEPTEMBER 2022 NEAR THE TIME OF THE CYCLONE'S ESTIMATED PEAK INTENSITY. IMAGE COURTESY OF NOAA/NESDIS STAR.

Madeline was a tropical storm that passed a little more than 100 n mi southwest of the coasts of southwestern Mexico and Baja California Sur. Outer rainbands from Madeline combined with a pre-existing surface trough to produce locally heavy rainfall along portions of the coast of southwestern Mexico which resulted in two flood-related fatalities.

Tropical Storm Madeline

16–20 SEPTEMBER 2022

SYNOPTIC HISTORY

Madeline's genesis pathway was unusual for an eastern Pacific tropical cyclone. The system's incipient disturbance appears to have originated from a thunderstorm complex that developed over southern Mexico early on 8 September, and then moved offshore near Acapulco, Mexico, before 1200 UTC that day. Although the thunderstorm activity associated with that disturbance waned late on 8 September, it left behind a surface trough offshore of the southern coast of Mexico that became the focus for additional thunderstorm activity during the overnight and early morning hours on 9 and 10 September. This activity resulted in the formation of a broad and elongated area of low pressure about 125 n mi southwest of Zihuatanejo, Mexico, by 1200 UTC 10 September. Early the next day, another burst of deep convection resulted in the formation of a small but well-defined low-pressure area by 1200 UTC 11 September about 190 n mi south of Manzanillo, Mexico. Over the next 24 to 36 h, the system nearly had enough convective organization to be classified as a tropical cyclone, but moderate easterly vertical wind shear caused the center to become exposed to the east of the convection while the convective activity inconsistently pulsed. A mid-level ridge centered over northern Mexico generally steered the low slowly westward during that time. By early on 13 September, increasing easterly shear caused the shower and thunderstorm activity to become even less organized and persistent. The next day, strengthening broad low-level cyclonic flow near the southern coast of Mexico due in part to another disturbance (which became Lester) near southeastern Mexico caused the low to turn southeastward. The low's forward speed slowed on 15 September, and as it meandered southeastward to southward, convective activity associated with the low remained disorganized in intermittent bursts removed from the center. Early on 16 September, despite the continued presence of moderate to strong easterly shear, convection increased and finally persisted near the low-level center. This evolution resulted in the formation of a tropical depression at 1800 UTC 16 September about 300 n mi south-southwest of Manzanillo, 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 1¹.

After formation, the tropical depression turned northeastward within the low- to mid-level broad cyclonic flow still located south of Mexico. The depression strengthened into Tropical Storm Madeline at 0600 UTC 17 September when it was located about 275 n mi south-southwest of Manzanillo. As Tropical Storm Lester, which was located well to the east of Madeline, moved inland over southern Mexico, and the steering effects of the broader-scale cyclonic flow lessened,

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 *bt* directory, while previous years' data are located in the *archive* directory.

this enabled Madeline to turn northward. The next day, a building mid-level ridge to the northeast of Madeline resulted in a northwestward motion by 1800 UTC 18 September. During the next 18 h while Madeline passed about 125 n mi southwest of the southwestern coast of Mexico, decreasing vertical wind shear allowed the tropical storm to strengthen. Madeline reached its estimated peak intensity of 55 kt at 1200 UTC 19 September when it was located about 150 n mi south-southeast of the southern tip of the Baja California peninsula. Shortly thereafter, the cyclone turned west-northwestward and moved into an area of less favorable thermodynamic conditions, causing the tropical storm to weaken. By 0000 UTC 20 September, Madeline moved over sea surface temperatures of less than 26°C as it passed a little over 100 n mi south of the southern tip of the Baja California peninsula. These cooler waters resulted in the deep convection dissipating during the morning hours of 20 September, and Madeline degenerated into a remnant low by 1200 UTC that day when it was centered about 140 n mi southwest of the southern tip of the Baja California peninsula.

The remnant low moved westward to west-northwestward during the next couple of days while it gradually weakened. On 22 September, when the low was located about 375 n mi west of the southern tip of the Baja California peninsula, it turned west-southwestward within the low-level trade wind flow. Thereafter, the low weakened but maintained a closed circulation for a few more days as it tracked west-southwestward over the open waters of the eastern Pacific. The low finally degenerated into a trough of low pressure shortly after 0000 UTC 25 September nearly 1000 n mi west of the southern tip of the Baja California peninsula.

METEOROLOGICAL STATISTICS

Observations in Madeline (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), 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 Madeline.

There were no ship reports of winds of tropical storm force in association with Madeline.

Winds and Pressure

Madeline's 55-kt peak intensity is based on a subjective Dvorak intensity estimate of T3.5 (55 kt) from TAFB at 1200 UTC 19 September. Objective ADT and SATCON estimates also peaked around that time but were slightly lower at 51 kt and 52 kt, respectively. The higher subjective estimate is supported by a 0357 UTC ASCAT-C overpass that revealed peak winds of 48 kt within the eastern portion of the cyclone's circulation. Given the continued improvement in

organization of Madeline in satellite imagery between the time of the ASCAT pass and 1200 UTC that morning, it is assumed additional strengthening occurred, and the estimated peak intensity is based on the higher subjective Dvorak estimate from TAFB. Madeline's minimum pressure of 991 mb is based on the Knaff-Zehr-Courtney pressure-wind relationship (Fig 3). There were no reports of sustained tropical-storm-force winds in Mexico; however, an observing site in the Islas Marias reported a wind gust to 36 kt at 1145 UTC 19 September while the center of Madeline passed about 130 n mi west-southwest of that station

Rainfall

The outer rainbands from Madeline combined with a pre-existing surface trough to produce locally heavy rainfall in portions of southern and southwestern Mexico on 17–19 September. However, a complete rainfall report has not been received at the time of this writing.

CASUALTY AND DAMAGE STATISTICS

There were no reports of significant damage associated with Madeline, however localized flooding is reported to have occurred in portions of southwestern Mexico. Media reports indicate that this flooding caused two fatalities, and one person was reported missing along a flooded stream in that area.

FORECAST AND WARNING CRITIQUE

The genesis of Madeline was well anticipated within a couple of days of the system's formation, but the longer-term genesis forecasts were not as good. The low from which Madeline formed was introduced into the Tropical Weather Outlook (TWO) at 1200 UTC 12 September with a low chance (<40%) of development over the next 2 and 5 days (Table 2). This provided 102 h of lead time before formation occurred. Although the system showed some signs of organization when it was introduced into the TWO, the probabilities remained in the low category during the next couple of days as it was anticipated that the low would merge with another disturbance (that became Lester) expected to form to the east of the pre-Madeline low. This expected evolution contributed to the less-than-adequate lead time for genesis of the 5-day probabilities. By 1200 UTC 14 September, that thinking changed as most of the global model guidance transitioned to solutions that kept the pre-Madeline low as a discrete system. At that time, the 2- and 5-day probabilities were raised to the medium category (40-60%) about 54 hours before formation occurred, and those chances were increased to the high category (>60%) with a Special TWO issued three hours later at 1500 UTC that day. Despite the difficulty in predicting the longer-range (5-day) chance of genesis of Madeline, the location of formation was well captured within nearly all the areas depicted on the NHC Graphical Tropical Weather Outlook (Fig. 4).

A verification of NHC official track forecasts for Madeline is given in Table 3a. Official track forecast errors were lower than the mean official errors for the previous 5-yr period, albeit

for a small sample size. The OCD5 errors were significantly larger than the 5-yr means, suggesting the forecasts for Madeline were more difficult than average. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The GFSI and CMCI models bested the official forecasts at 12 and 24 h, and they were the only individual models that had lower mean errors than the official forecast at more than one verifying lead time. The NHC forecast also performed well compared to the various consensus aids. The simple consensus aid TVCE exhibited errors slightly lower than the official forecasts at 12, 24, and 48 h, but no other simple or corrected consensus aid bested the official forecast at more than two verifying lead times. The NHC forecasts had the lowest mean track errors at 36 h. The first couple of NHC forecasts suffered from a southward bias (Fig. 5) as compared to the remainder of the track forecasts for Madeline.

A verification of NHC official intensity forecasts for Madeline is given in Table 4a. Official intensity forecast errors were lower than the mean official errors for the previous 5-yr period at all verifying lead times. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official intensity forecasts performed well as compared to the various intensity aids. The HWRF (HWFI) was the only model that performed better than the official forecast at more than one verifying lead time, besting it at 12, 24, and 36 h. No other intensity aids performed better than the NHC forecast at 24, 36, and 48 h. The first NHC forecast correctly predicted that Madeline would reach an intensity of around 50 kt. Subsequent forecasts called for a slightly lower peak intensity, but overall, the forecasts were quite accurate. The early NHC forecasts called for Madeline to remain a tropical cyclone for the entire 5-day forecast period, but the storm weakened and degenerated into a remnant low much sooner.

A Tropical Storm Watch was issued by the government of Mexico for a portion of the southwestern coast of Mexico at 0900 UTC 18 September (Table 5), primarily due to the large tropical-storm-force wind field on the southeastern side of Madeline and an initial northeastward shift of the track forecast during that period (Fig. 5). However, this watch was discontinued about 18 h later, after Madeline began moving away from that area and the wind field over the eastern semicircle decreased in size.



Table 1. Best track for Tropical Storm Madeline, 16–20 September 2022.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
11 / 1200	15.8	104.2	1008	20	low
11 / 1800	15.8	104.9	1008	20	"
12 / 0000	15.7	105.6	1008	20	"
12 / 0600	15.7	106.2	1007	25	"
12 / 1200	15.7	106.8	1007	25	"
12 / 1800	15.7	107.4	1007	25	"
13 / 0000	15.7	107.8	1007	25	"
13 / 0600	15.8	108.1	1008	20	"
13 / 1200	15.9	108.3	1008	20	"
13 / 1800	16.0	108.5	1008	20	"
14 / 0000	16.0	108.6	1008	20	"
14 / 0600	16.0	108.6	1008	20	"
14 / 1200	15.7	108.4	1007	25	"
14 / 1800	15.5	108.1	1007	25	"
15 / 0000	15.3	107.7	1007	25	"
15 / 0600	15.2	107.3	1007	25	"
15 / 1200	15.2	106.9	1007	25	"
15 / 1800	15.1	106.8	1007	25	"
16 / 0000	15.0	106.8	1007	25	"
16 / 0600	14.8	107.0	1007	25	"
16 / 1200	14.6	107.0	1007	25	"
16 / 1800	14.6	106.8	1006	30	tropical depression
17 / 0000	14.7	106.6	1005	30	"
17 / 0600	14.9	106.5	1004	35	tropical storm
17 / 1200	15.3	106.5	1002	40	"
17 / 1800	15.8	106.7	1001	40	"
18 / 0000	16.5	106.7	999	40	"



Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
18 / 0600	17.3	106.7	998	40	"
18 / 1200	18.0	106.8	997	40	"
18 / 1800	18.6	107.1	997	40	"
19 / 0000	19.2	107.5	996	45	"
19 / 0600	19.9	108.0	993	50	"
19 / 1200	20.5	108.7	991	55	"
19 / 1800	20.8	109.5	993	50	"
20 / 0000	21.0	110.3	997	45	"
20 / 0600	21.0	111.0	1002	35	"
20 / 1200	21.1	111.6	1005	30	low
20 / 1800	21.2	112.2	1005	30	"
21 / 0000	21.4	112.8	1005	30	"
21 / 0600	21.6	113.5	1005	30	"
21 / 1200	21.7	114.2	1005	30	"
21 / 1800	21.8	115.0	1006	25	"
22 / 0000	21.9	115.8	1007	25	"
22 / 0600	21.9	116.5	1008	25	"
22 / 1200	21.8	117.1	1008	25	"
22 / 1800	21.7	117.8	1008	25	"
23 / 0000	21.6	118.6	1009	20	"
23 / 0600	21.5	119.4	1009	20	"
23 / 1200	21.3	120.6	1009	20	"
23 / 1800	21.0	121.8	1009	20	"
24 / 0000	20.8	122.9	1009	20	"
24 / 0600	20.6	124.0	1009	20	"
24 / 1200	20.4	124.9	1009	20	"
24 / 1800	20.3	125.9	1009	20	"
25 / 0000	20.2	126.8	1009	20	"



Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
25 / 0600					dissipated
19 / 1200	20.5	108.7	991	55	maximum wind 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 (<40%)	102	102
Medium (40%-60%)	54	54
High (>60%)	51	51



Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Madeline, 16–20 September 2022. 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	60	72	96	120
OFCL	20.3	27.0	26.8	32.0	39.7			
OCD5	43.9	91.3	158.7	189.4	190.2			
Forecasts	9	7	5	3	1			
OFCL (2017-21)	21.9	33.8	45.6	56.9	74.8	79.9	99.5	121.3
OCD5 (2017-21)	35.8	72.3	112.7	155.0	198.7	239.0	309.2	372.2



Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Madeline, 16–20 September 2022. 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	60	72	96	120
OFCL	19.7	24.6	19.5	21.3				
OCD5	40.9	88.4	158.9	189.6				
GFSI	18.0	21.3	26.9	45.5				
HMNI	21.2	25.0	40.4	15.7				
HWFI	26.4	37.1	41.0	74.6				
EGRI	25.3	35.2	36.9	37.5				
EMXI	26.1	39.2	38.3	31.8				
CMCI	18.4	21.4	31.4	35.9				
NVGI	38.4	71.1	110.6	162.0				
CTCI	16.3	30.7	52.3	77.5				
AEMI	16.2	20.0	36.5	52.5				
HCCA	20.0	22.1	22.6	17.4				
FSSE	18.2	22.5	22.0	22.1				
TVCX	19.0	24.2	24.0	24.0				
GFEX	20.2	25.8	25.7	27.2				
TVCE	17.9	20.4	20.6	19.9				
TVDG	19.8	23.6	22.9	25.3				
TABD	29.1	33.7	44.3	61.1				
TABM	34.6	59.1	73.3	73.6				
TABS	55.8	117.5	163.8	179.9				
Forecasts	8	6	4	2				



Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Madeline, 16–20 September 2022. 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	60	72	96	120
OFCL	4.4	5.7	4.0	0.0	10.0			
OCD5	7.1	9.4	6.0	8.3	26.0			
Forecasts	9	7	5	3	1			
OFCL (2017-21)	5.5	9.1	11.1	12.9	15.3	15.6	16.4	17.0
OCD5 (2017-21)	7.0	12.2	15.8	18.6	20.4	21.2	22.3	21.8



Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Madeline, 16–20 September 2022. 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	60	72	96	120
OFCL	4.4	5.8	5.0	0.0				
OCD5	7.0	8.7	5.2	7.5				
GFSI	4.0	6.2	5.2	1.0				
HMNI	4.9	7.2	10.0	7.5				
HWFI	4.2	5.3	4.2	0.5				
CTCI	3.9	6.5	7.8	3.0				
EMXI	5.4	8.3	9.2	6.5				
DSHP	5.8	9.3	9.5	8.5				
LGEM	6.9	11.3	12.5	10.0				
ICON	4.8	8.2	8.8	6.5				
IVCN	4.5	7.7	8.0	5.5				
IVDR	4.1	6.8	7.2	4.0				
HCCA	4.4	6.2	6.8	3.5				
FSSE	4.5	6.3	6.8	2.5				
Forecasts	8	6	4	2				



Table 5. Watch and warning summary for Tropical Storm Madeline, 16–20 September 2022.

Date/Time (UTC)	Action	Location
18 / 0900	Tropical Storm Watch issued	Manzanillo to Cabo Corrientes
19 / 0300	Tropical Storm Watch discontinued	All

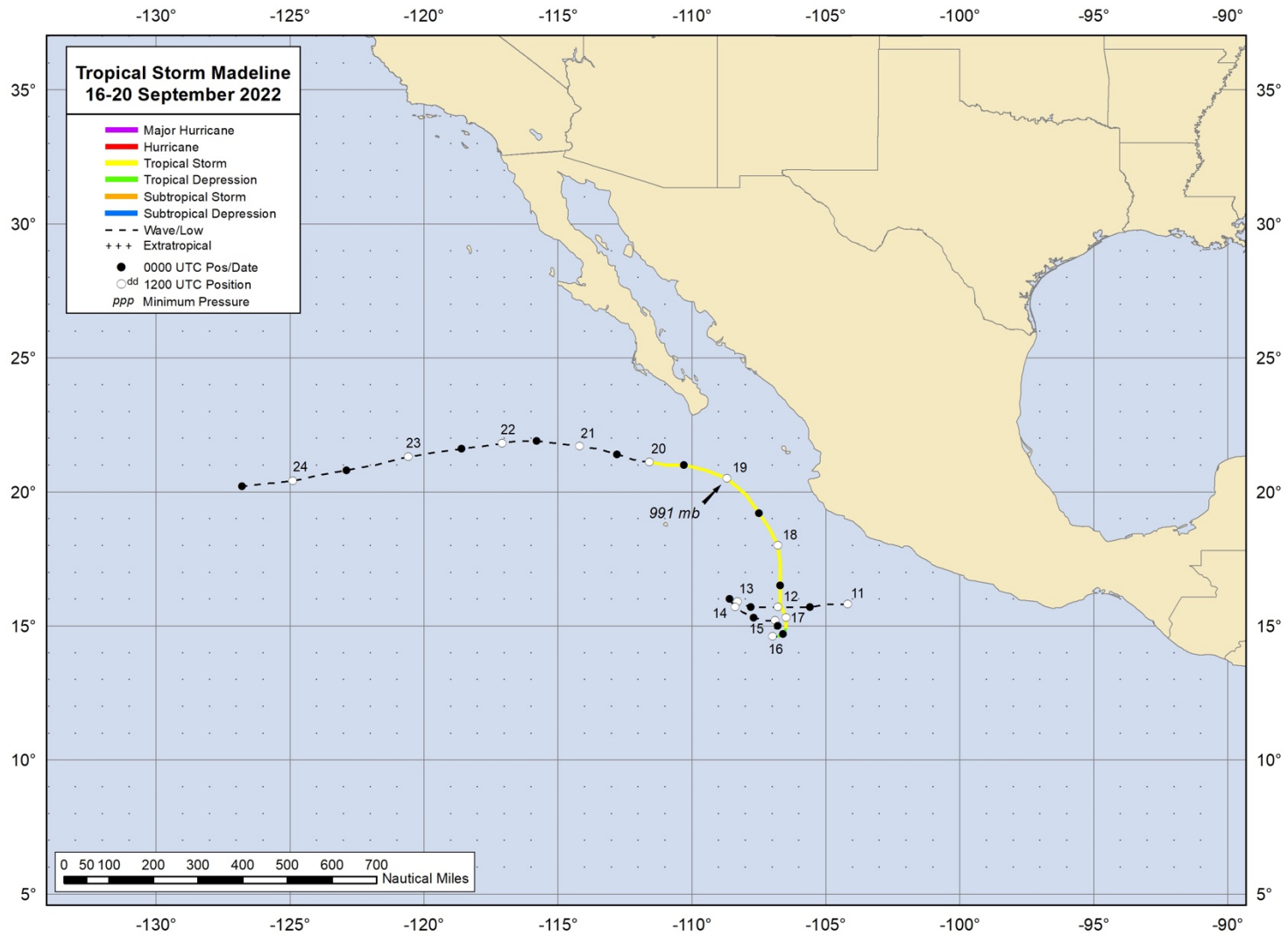


Figure 1. Best track positions for Tropical Storm Madeline, 16–20 September 2022.

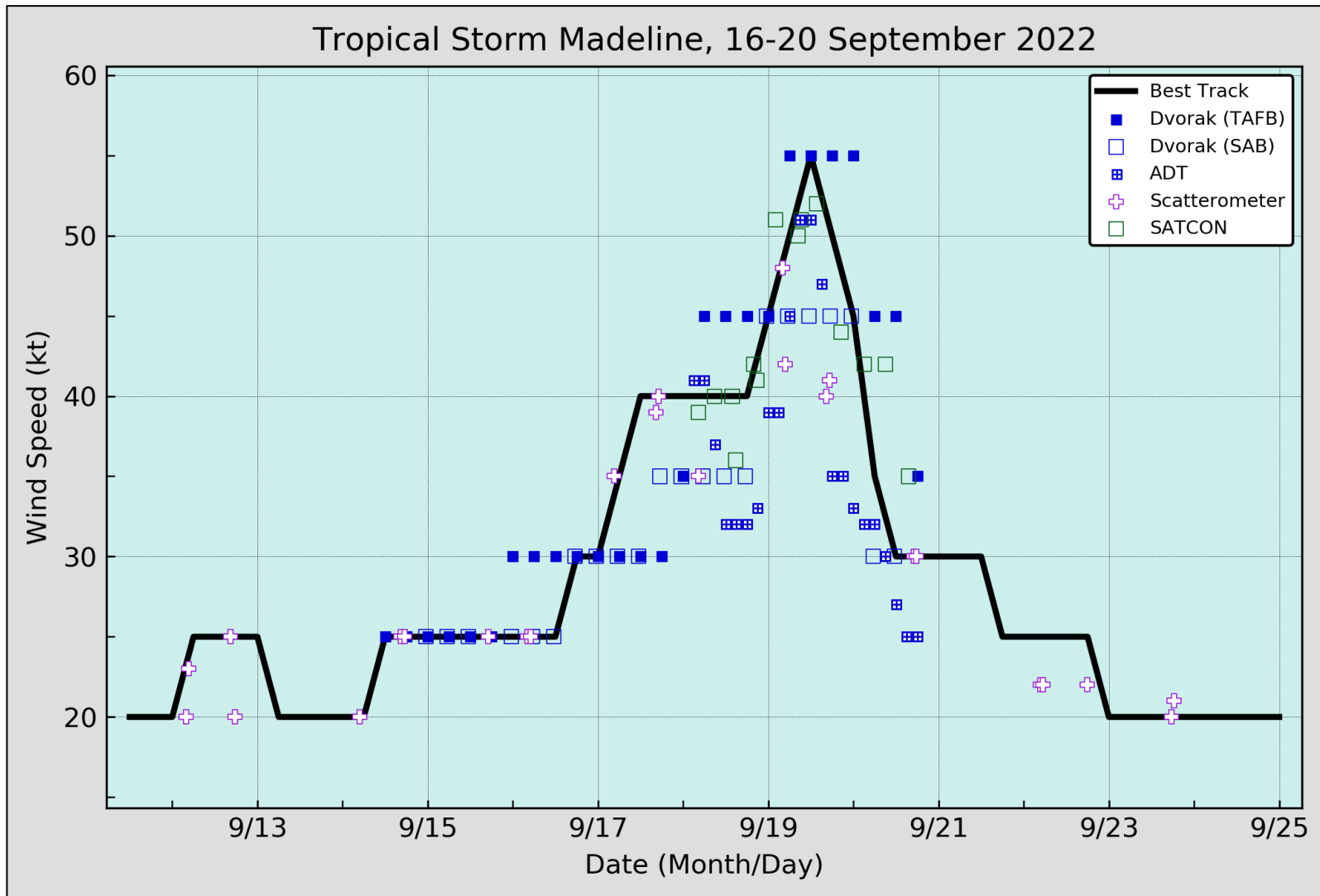


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Madeline, 16–20 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

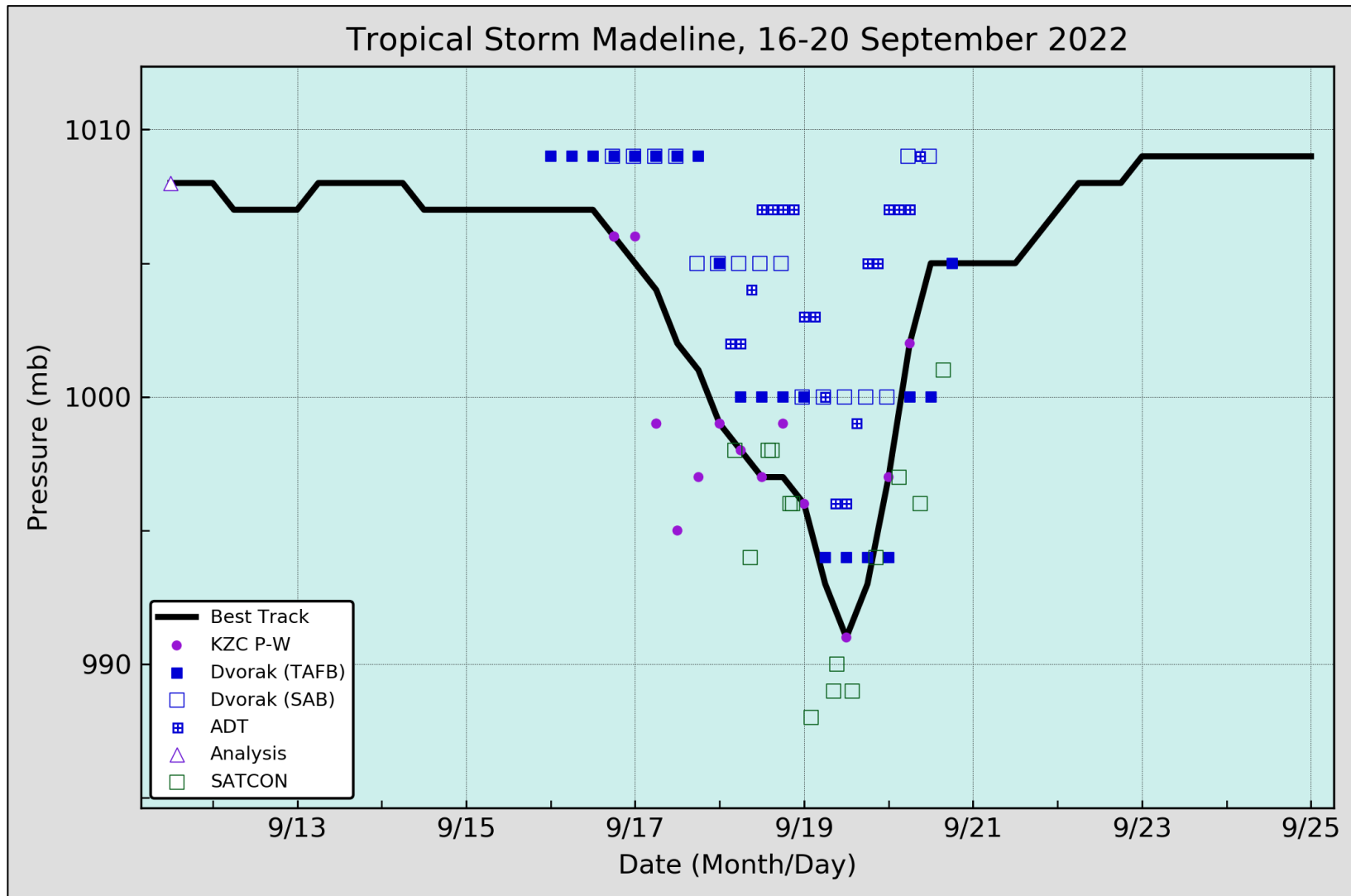


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Madeline, 16–20 September 2022. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute 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.

Madeline 5-day Tropical Weather Outlook Areas

From: 1200 UTC 12 Sep 2022 to 1800 UTC 16 Sep 2022

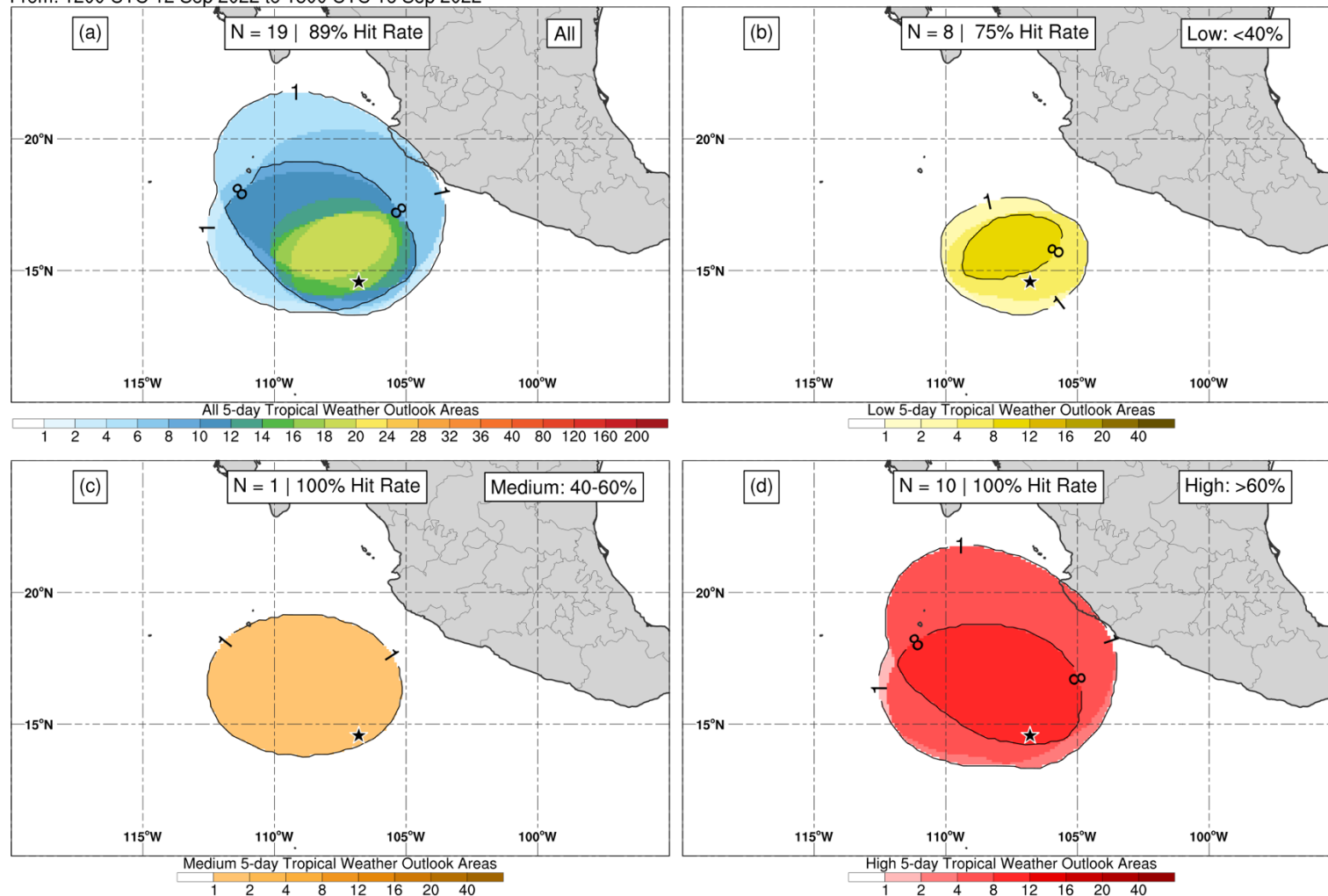


Figure 4. 5-day Tropical Weather Outlook genesis areas associated with the disturbance that developed into Tropical Storm Madeline for (a) all probability areas (10–100%, multi-color shading), (b) low probability areas (< 40%, yellow shading), (c) medium probability areas (40–60%, orange shading), and (d) high probability areas (> 60%, red shading). The black star in each panel indicates the genesis location of Madeline. Hit rate indicates the percentage of outlook areas that the genesis location was captured within.

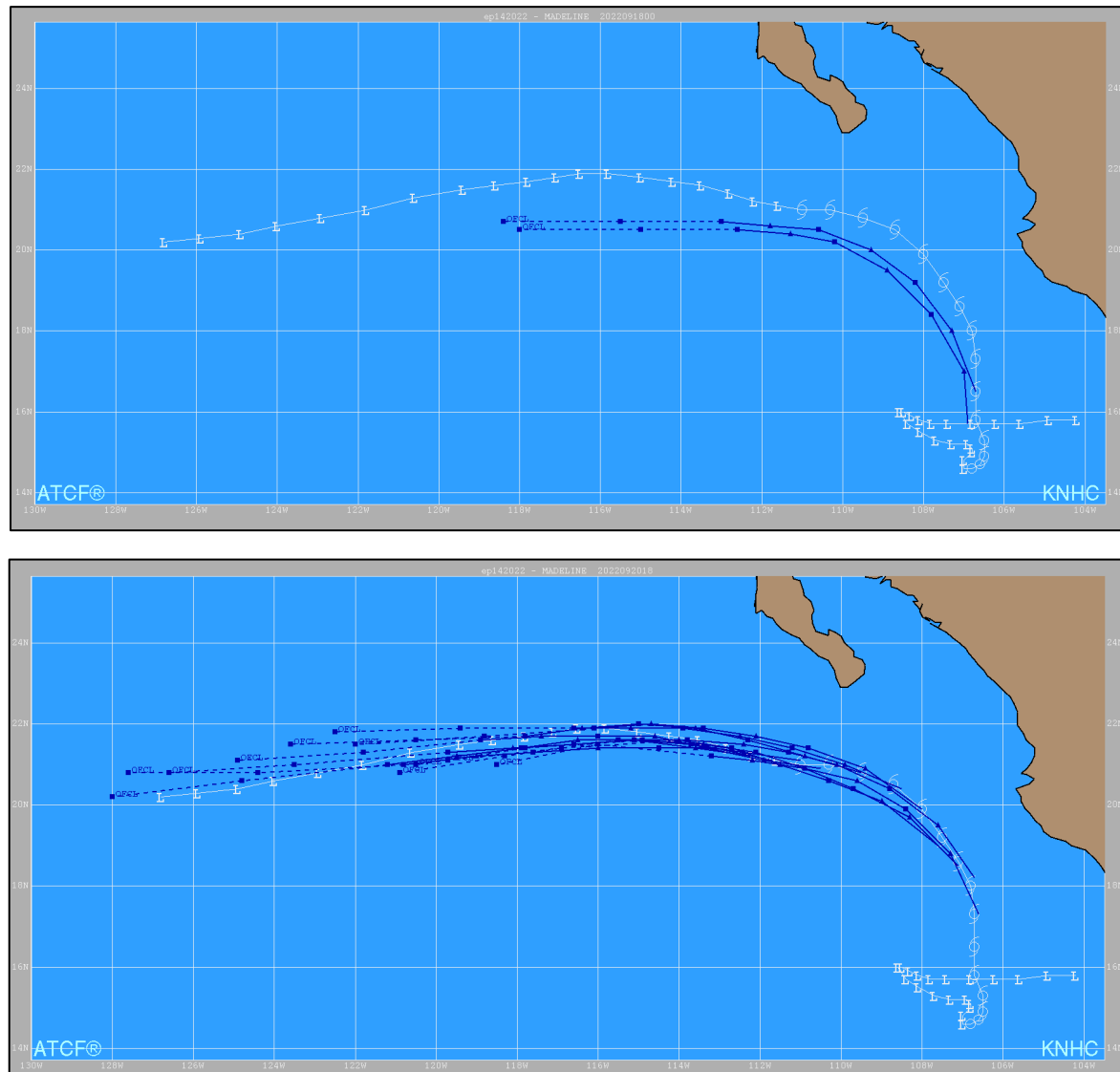


Figure 5. The first two official NHC track forecasts (top) and the remaining official track forecasts (bottom) for Tropical Storm Madeline, 16–20 September 2022. Note the southward bias of the early forecasts (top) as compared to the remainder of the forecasts (bottom) for Madeline. The actual track of Madeline is denoted by the white symbols plotted at 6-h intervals.