NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM DOLORES

(EP042021)

18–20 June 2021

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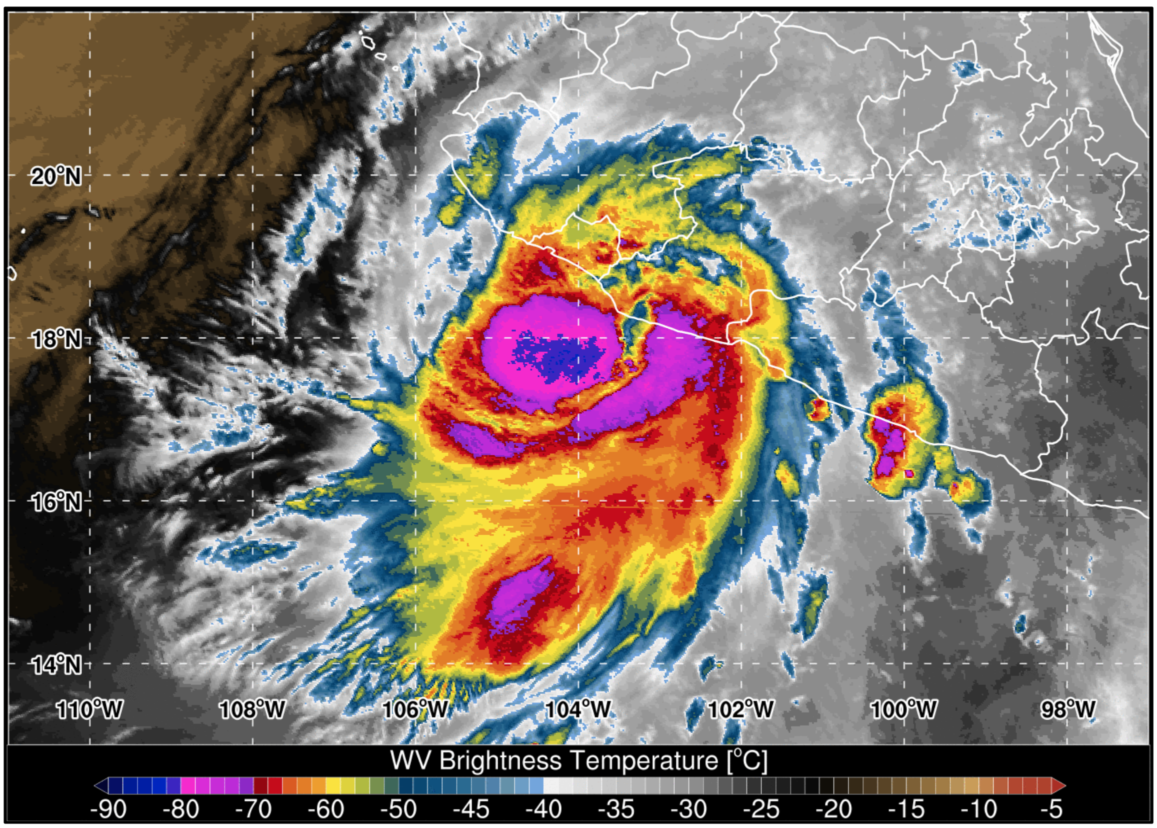

GOES-16 WATER VAPOR IMAGE AT 1200 UTC 19 JUNE 2021, SHOWING TROPICAL STORM DOLORES NEAR PEAK INTENSITY. DATA USED TO CREATE THIS SATELLITE IMAGE COURTESY OF THE NOAA BIG DATA PROJECT.

Dolores was a 60-kt tropical storm that made landfall in Mexico, near the state borders of Michoacán and Colima on 19 June. The storm was a heavy rainfall producer that resulted in significant flooding across southwestern Mexico. Three direct fatalities were attributed to the storm due to lightning in Oaxaca and Jalisco.

Tropical Storm Dolores

18–20 JUNE 2021

SYNOPTIC HISTORY

Dolores's origins appear to be related to a convectively enhanced monsoon trough that developed over the far eastern Pacific on 9–10 June. Shortly after this time, a tropical wave crossed Central America and interacted with this monsoonal flow, resulting in the formation of a broad cyclonic circulation over Central America by 12 June. This broader circulation briefly resembled a Central American Gyre[1], though the larger-scale circulation did not persist long enough to achieve that classification. The northern portion of this feature meandered in the Bay of Campeche over the next 2–4 days before ejecting out to the northeast and developing into Tropical Storm Claudette over the Gulf of Mexico on 19 June. The southern portion of this circulation continued to produce diurnal bursts of deep convection over the next several days, eventually leading to the formation of another area of low pressure by 16 June over the eastern Pacific waters a couple of hundred n mi south of the Mexican coastline.

Over the following day, disorganized convection continued to wax and wane, but gradually became more concentrated near the area of low pressure. Scatterometer surface wind data indicated that a well-defined center formed around 1800 UTC 17 June about 170 n mi south of Acapulco, Mexico, while the system moved slowly to the west-northwest along the southern extent of a weak low- to mid-level ridge over Mexico. That evening, convection consolidated further and became better organized, resulting in the formation of a tropical depression by 0600 UTC 18 June about 150 n mi south-southwest of Acapulco, Mexico. The depression strengthened into a tropical storm six hours later. The "best track" chart of Dolores'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[2].

A mid-level ridge initially steered Dolores to the west-northwest but, over the following day, a pronounced weakness developed north of the tropical cyclone as the ridge shifted farther to the east. This pattern resulted in Dolores's motion shifting poleward, first northwestward and then north-northwestward on 18 June as the system approached the southwestern coast of Mexico. Dolores continued to intensify in an environment of low vertical wind shear, high mid-level moisture, and warm (28–29^{o}C) sea surface temperatures, and the cyclone reached a peak intensity of 60 kt by 1200 UTC 19 June. Around that time, passive microwave imagery indicated that the system was developing an eyewall (Fig. 4) embedded within deep, cold convective cloud

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[1] A Central American gyre (CAG) is a broad lower-tropospheric cyclonic circulation occurring near Central America. For more information, please refer to Papin, P., L. F. Bosart, R. D. Torn, 2017: A Climatology of Central American Gyres. *Mon. Wea. Rev*., **145**, 1983–2000.

[2] 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.

top temperatures between -70 to -80°C (cover photo). However, there was little time for additional intensification as the storm accelerated to the north-northwest. Dolores made landfall at 1500 UTC 19 June as a 60-kt tropical storm near the small town of San Juan de Alima, Mexico, or about 45 n mi southeast of Manzanillo, Mexico.

After Dolores moved inland, the storm quickly weakened as it passed over the high, rugged terrain of southwestern Mexico. Dolores weakened to a tropical depression by 0000 UTC 20 June and dissipated shortly thereafter over western Mexico. However, after the cyclone dissipated, heavy rains associated with the moisture field of the system continued for another 12–24 hours over west-central Mexico.

METEOROLOGICAL STATISTICS

Observations in Dolores (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 Dolores.

Winds and Pressure

The 60-kt peak intensity of Dolores at 1200–1500 UTC 19 June is based on a blend of subjective and objective Dvorak satellite intensity estimates from TAFB (T3.5/55 kt), SAB (T4.5/77 kt), and ADT (T3.6/57 kt). In addition, a SATCON estimate of 60 kt was provided at 1420 UTC 19 June, shortly before Dolores made landfall. The estimated minimum pressure of 989 mb is based on the Knaff-Zehr-Courtney pressure wind relationship, which also matches the SATCON intensity estimate just prior to landfall. However, given the lack of in-situ observations available for Dolores at the time of landfall, there remains some uncertainty in this estimate, especially given the well-organized microwave presentation (Fig. 4). Readers are reminded that the average best-track uncertainty estimate for intensity is around +/-10 kt for tropical storms with only satellite-based observations[3].

Dolores made landfall in a region with limited coastal observations and, as of this writing, only one elevated land observing site reported sustained tropical-storm-force winds. The highest sustained wind report was 36 kt gusting to 56 kt from an elevated station (3428 m) near Nevado de Colima Volcano at 1810 UTC 19 June. Another elevated station (2509 m) in the mountains at Sierra Manantlán reported a wind gust of 58 kt at 1310 UTC 19 June, while another elevated

[3] Landsea, C. W., and J. L. Franklin, 2013: Atlantic hurricane database uncertainty and presentation of a new database format. *Mon. Wea. Rev.*, **141**, 3576–3592.

station (723 m) in Colima reported a peak gust of 45 kt at 1340 UTC 19 June. Significant onshore wind gusts were observed on the eastern side of Dolores within larger-scale monsoonal flow, with a wind gust up to 38 kt observed on the coast in Puerto Vicente at 0345 UTC 19 June. Lastly, there was one reliable ship report of tropical-storm-force winds associated with Dolores. The ship *Maersk Yukon* (call sign 9V6458) reported a sustained 38-kt wind to the southeast of the center in the monsoonal flow at 0000 UTC 19 June.

Rainfall and Flooding

Dolores produced a large region of significant rainfall exceeding 5 inches (~125 mm) along and inland of the southwestern coast of Mexico, affecting the Mexican states of Guerrero, Michoacán, Colima, and Jalisco between 18–20 June (Fig. 5). The highest rainfall total occurred in Colima, with 17.31 inches (439.9 mm) reported in Callejones. Cerro de Ortega and Laguna de Amela reported 15.66 and 12.87 inches (397.8 and 326.9 mm), respectively. In Michoacán, the highest rainfall amount was in Coahuayana at 11.35 inches (288.5 mm) while in Jalisco the highest total was 7.35 inches (186.8 mm) in Solidaridad. Somewhat lower totals of 3–6 inches (75–150 mm) were prevalent along the coast of Guerrero. However, this state in addition to Oaxaca had been affected by longer-duration rainfall stemming back to the larger-scale circulation that developed over Central America which contributed to the formation of both Claudette and Dolores.

CASUALTY AND DAMAGE STATISTICS

There were three direct deaths[4] associated with Dolores, which all appear to be due to lightning. Two people died in San Nicolas, Oaxaca, while another man died in Ciudad Guzman, Jalisco after apparently being struck by lightning on a soccer field.

Heavy rainfall from Dolores was responsible for significant flooding across mainland Mexico in Guerrero, Michoacán, Colima, and Jalisco. At least 20 municipalities in Michoacán were affected by flooding and wind-downed trees, leading to many blocked roads in these communities (Fig. 6). In Jalisco, at least 80 houses were temporarily isolated due to flooding when the Marabasco River overflowed its banks. Overall, more than 50,000 customers lost power across the southwestern states of Mexico.

According to the July 2021 global catastrophe report from Aon, Dolores resulted in more than $50 million (USD) of estimated economic losses in Mexico with more than 1000 structures affected.

[4] 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.

FORECAST AND WARNING CRITIQUE

The genesis of Dolores was fairly well anticipated. Table 2 provides the number of hours in advance of formation with the first Tropical Weather Outlook (TWO) forecast in each likelihood category, and Figure 7 shows the spatial distribution of the 5-day TWO areas for each category. A low (<40%) chance of genesis in the east Pacific during the next 5 days was first introduced 108 h before development occurred. The 5-day probabilities were increased to the medium (40–60%) and high (>60%) categories 84 h and 36 h before Dolores developed, respectively. The location of genesis was also well anticipated, with 100% of all outlook areas capturing Dolores' genesis location (Figs. 7a-d). For the 2-day probabilities, the pre-Dolores system was given a low, medium, and high chance of genesis, 60 h, 36 h, and 24 h before formation, respectively.

A verification of NHC official track forecasts for Dolores is given in Table 3a. Official track forecast errors were greater than the mean official errors for the previous 5-yr period, especially at 36-h, which was nearly three times the mean error for that period (albeit with a small sample size). Climatology-persistence (OCD5) track errors were also much higher than their respective 5-yr means from 12–36 h, suggesting that Dolores's track was harder-than-usual to forecast for a typical eastern Pacific tropical cyclone. The first couple of official track forecasts were too far to the west and slow relative to the verifying track (Fig. 8), contributing to the significant track error in the overall statistics. Subsequent track forecasts captured the correct track evolution inland over southwestern Mexico, though these later forecasts only verified for the 12–24 h forecast periods since Dolores dissipated quickly after landfall.

A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Of the deterministic guidance, only the GFS (GFSI) and HMON (HMNI) beat the official forecast track errors at each verifying forecast time (12–36 h). These lower errors are notable, since these models were initially the farthest east track guidance, correctly indicating an earlier landfall in Mexico compared to other deterministic guidance such as the ECMWF (EMXI), UKMET (EGRI), and Canadian (CMCI). Of the track consensus aids, the HFIP corrected consensus (HCCA), the GFS ensemble (AEMI), and a simple consensus of the GFS and ECMWF (GEFX) all outperformed the official track forecast at all verifying times. Interestingly, the simple Medium- and Deep-Layer Trajectory Beta track models (TABM and TABD) did as well, suggesting that Dolores' increasing vertical depth likely led to the more eastward motion of the storm, and may have contributed to the unusually large mean track errors of some of the dynamical models.

A verification of NHC official intensity forecasts for Dolores is given in Table 4a. Official intensity forecast errors were lower than the mean official errors for the previous 5-yr period for 12–24 h, but higher for 36 h (albeit with a small sample size). Overall, the official intensity forecasts correctly anticipated that Dolores would intensify to near hurricane strength. However, the first couple forecasts kept Dolores further offshore at 36 h (Fig. 8), leading to a high intensity bias at that forecast period. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. While the official intensity forecast outperformed the guidance at 12 h, HWRF (HWFI) and HCCA bettered the official forecasts at 24 h, and all guidance beat the official forecasts at 36 h (though with only a limited sample size).

Coastal watches and warnings associated with Dolores are given in Table 5.

ACKNOWLEDGMENTS

Special thanks to Senior Hurricane Specialist John Cangialosi for the Dolores "best track" map (Fig. 1).

Table 1. Best track for Tropical Storm Dolores, 18–20 June 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
17 / 1800	14.0	99.7	1007	25	low
18 / 0000	14.2	100.4	1005	30	"
18 / 0600	14.4	101.1	1005	30	tropical depression
18 / 1200	14.7	101.7	1004	35	tropical storm
18 / 1800	15.3	102.2	1000	40	"
19 / 0000	16.0	102.6	998	45	"
19 / 0600	16.8	103.1	995	50	"
19 / 1200	17.9	103.5	989	60	"
19 / 1500	18.6	103.7	989	60	"
19 / 1800	19.4	103.9	997	50	"
20 / 0000	21.4	104.1	1001	30	tropical depression
20 / 0600					dissipated
19 / 1200	17.9	103.5	989	60	Maximum wind and minimum pressure
19/ 1500	18.6	103.7	989	60	Landfall near San Juan de Alima, Mexico

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%)	60	108
Medium (40%-60%)	36	84
High (>60%)	24	36

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Dolores, 18–20 June 2021. 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	39.2	72.3	130.2					
OCD5	80.9	183.1	320.0					
Forecasts	6	4	2					
OFCL (2016-20)	21.3	33.1	44.0	54.6	65.3	76.0	95.9	116.6
OCD5 (2016-20)	33.1	69.4	107.8	147.0	183.4	219.7	280.2	342.0

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Dolores, 18–20 June 2021. 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	31.0	72.3	130.2					
OCD5	69.8	183.1	320.0					
GFSI	**24.0**	**36.0**	**77.9**					
EMXI	42.0	91.5	151.4					
EGRI	46.0	98.6	165.2					
CMCI	35.6	74.3	148.0					
NVGI	50.9	95.1	**110.5**					
HWFI	33.9	**68.9**	**108.3**					
HMNI	**26.0**	**43.7**	**77.9**					
HCCA	**29.7**	**66.2**	**119.3**					
AEMI	**28.0**	**56.9**	**130.1**					
GFEX	**28.3**	**57.8**	**110.7**					
TVCA	32.7	**71.8**	**126.4**					
TVCX	32.0	**70.5**	**127.6**					
TVDG	32.5	**68.2**	**126.9**					
TABS	45.8	134.1	198.0					
TABM	**27.0**	**69.0**	**104.9**					
TABD	**25.3**	**39.3**	**65.8**					
Forecasts	4	4	2					

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Dolores, 18–20 June 2021. 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	**5.0**	**5.0**	17.5					
OCD5	8.0	12.5	11.0					
Forecasts	6	4	2					
OFCL (2016-20)	5.6	9.0	10.9	12.6	14.0	15.3	16.0	16.7
OCD5 (2016-20)	7.2	12.0	15.3	17.6	19.0	20.4	21.2	20.8

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Dolores, 18–20 June 2021. 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	2.5	5.0	17.5					
OCD5	6.0	12.5	**11.0**					
HWFI	6.0	**3.0**	**7.5**					
HMNI	6.2	5.8	**5.5**					
DSHP	5.2	10.2	**5.0**					
LGEM	7.0	12.8	**8.0**					
ICON	3.8	5.0	**4.0**					
IVCN	3.8	5.0	**4.0**					
IVDR	4.2	**3.2**	**1.5**					
HCCA	3.2	**3.2**	**7.5**					
GFSI	6.0	13.0	**9.5**					
EMXI	9.0	13.5	**11.0**					
EGRI	6.0	8.2	**9.5**					
CMCI	11.0	13.5	**12.0**					
NVGI	7.2	11.8	**13.5**					
Forecasts	4	4	2					

Table 5. Watch and warning summary for Tropical Storm Dolores, 18–20 June 2021.

Date/Time (UTC)	Action	Location
18 / 0900	Tropical Storm Watch issued	Cabo Corrientes to Lazaro Cardenas
18 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Cabo Corrientes to Lazaro Cardenas
18 / 1500	Tropical Storm Watch issued	Escuinapa to Cabo Corrientes
18 / 1500	Hurricane Watch issued	Cabo Corrientes to Punta San Telmo
19 / 0900	Hurricane Watch modified to	Cabo Corrientes to Lazaro Cardenas
19 / 1800	Hurricane Watch changed to Tropical Storm Warning	Cabo Corrientes to Lazaro Cardenas
20 / 0000	Tropical Storm Watch discontinued	All
20 / 0000	Tropical Storm Warning discontinued	All

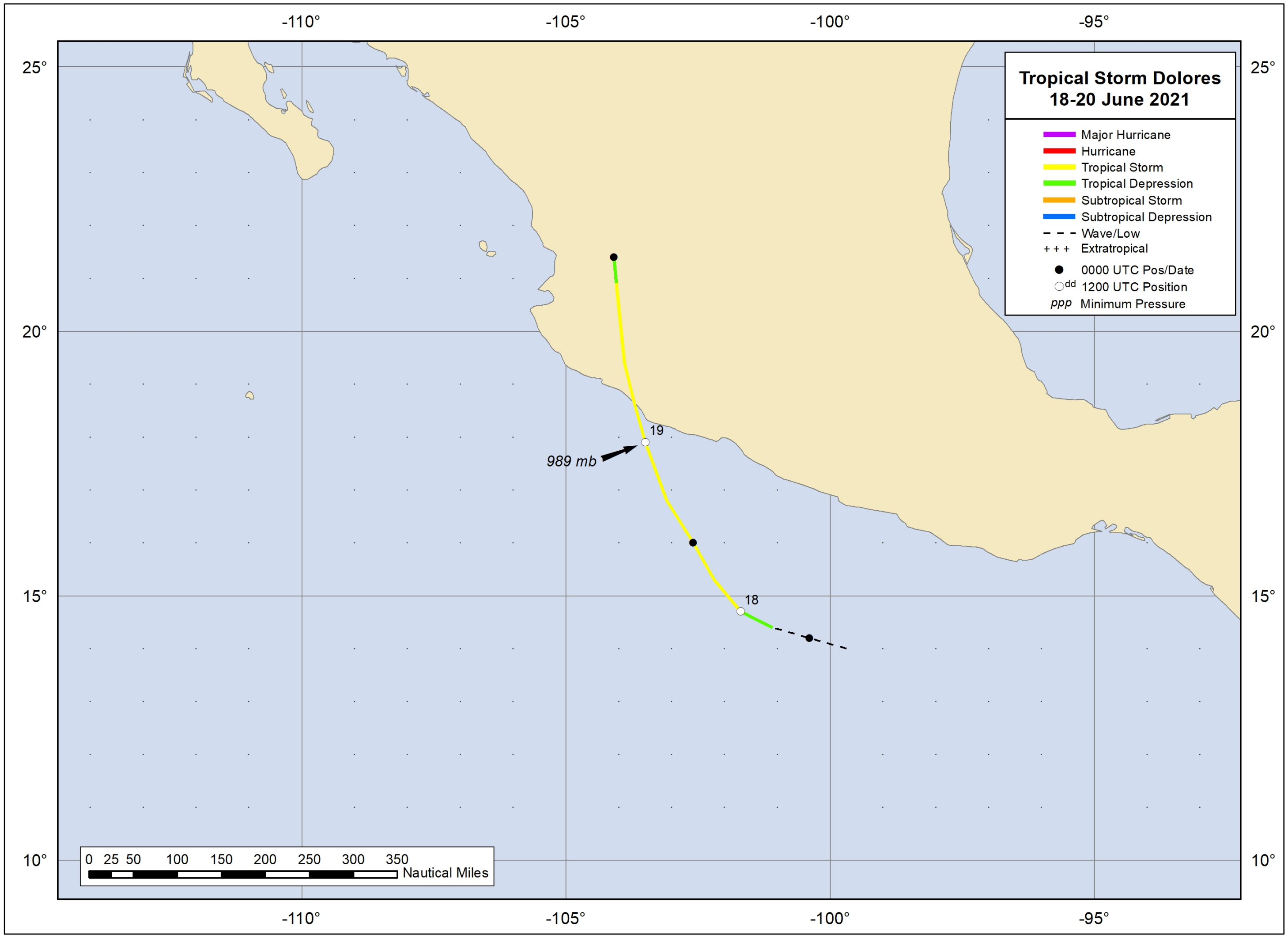

Figure 1. Best track positions for Tropical Storm Dolores, 18–20 June 2021.

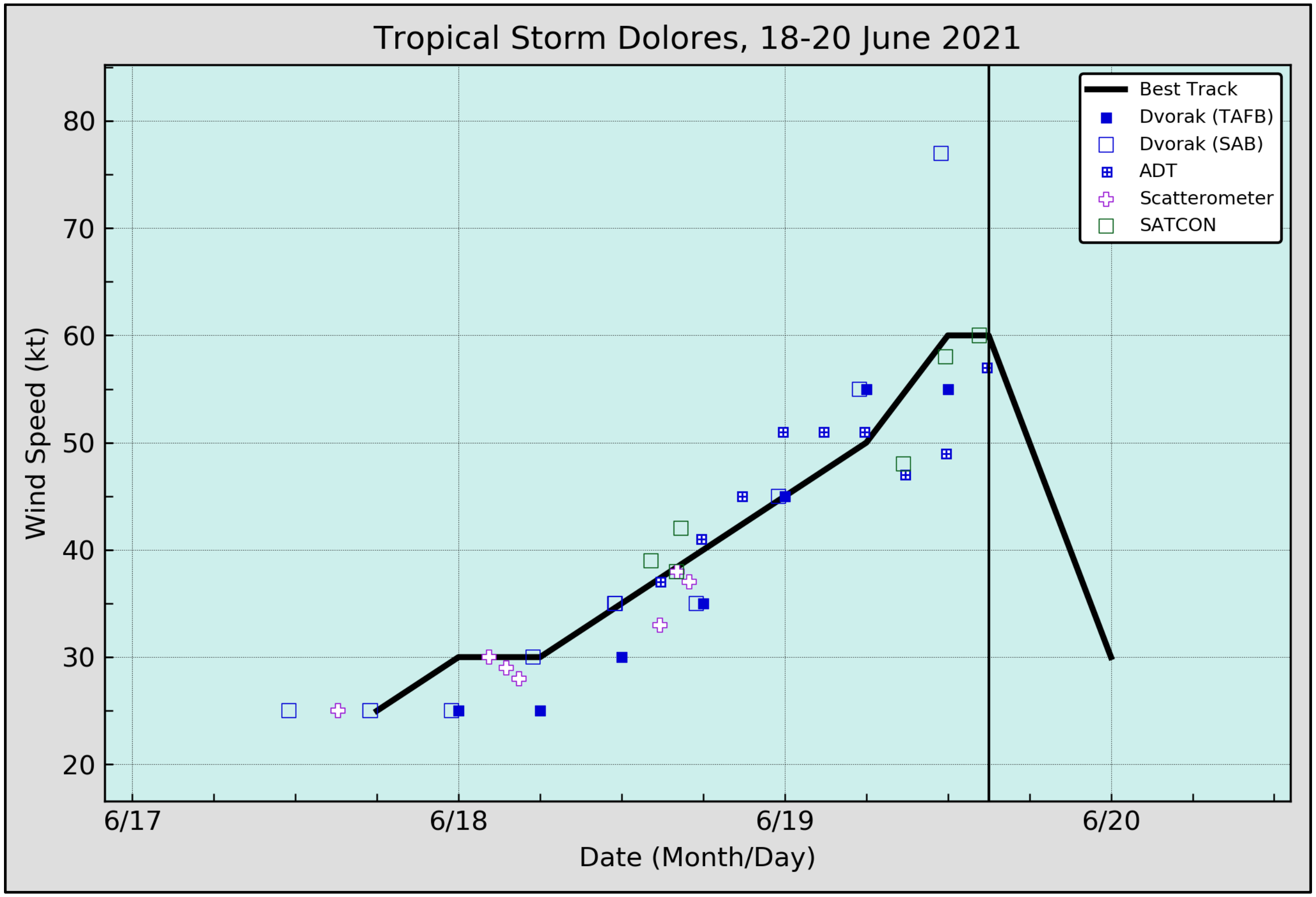

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Dolores, 18–20 June 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC, and the solid vertical line corresponds to landfall.

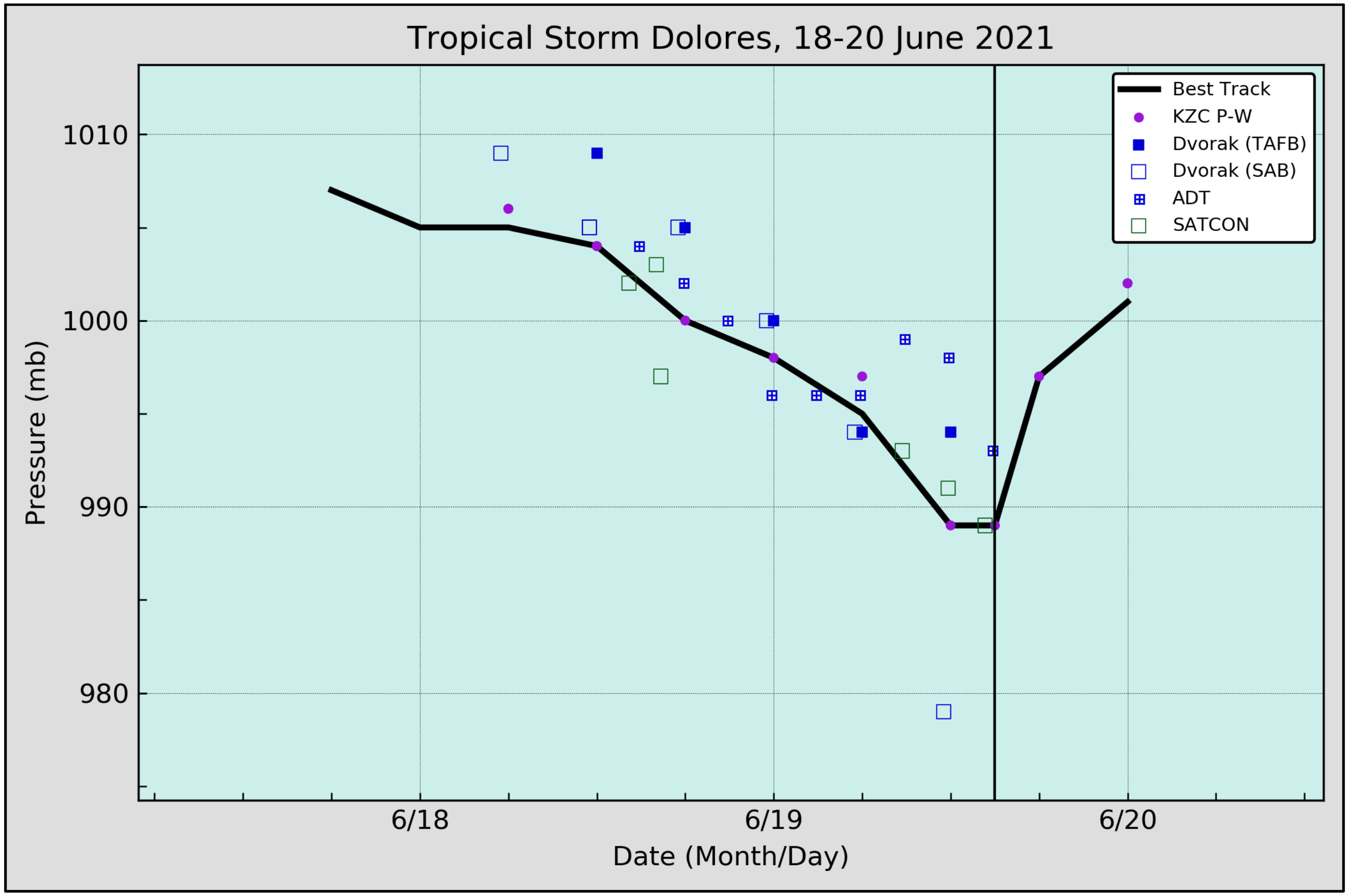

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Dolores, 18–20 June 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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, and the solid vertical line corresponds to landfall.

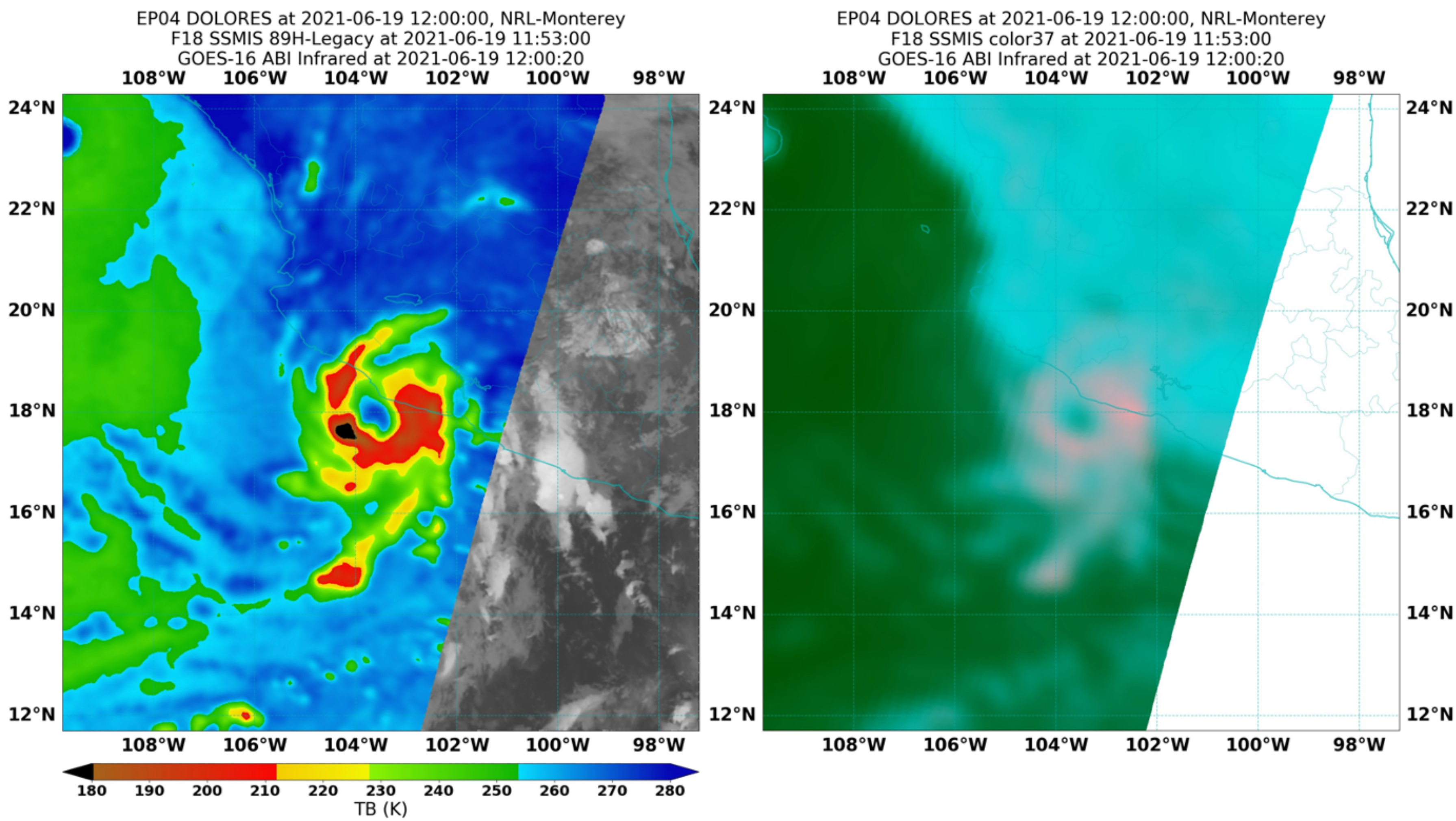

Figure 4. Passive SSMIS microwave satellite imagery of Tropical Storm Dolores near peak intensity at 1153 UTC 19 June 2021 for the (a) 89-GHz channel brightness (shaded, K) and (b) 37-GHz color composite imagery. Note the ring of convection in both panels signifying a formative eyewall.

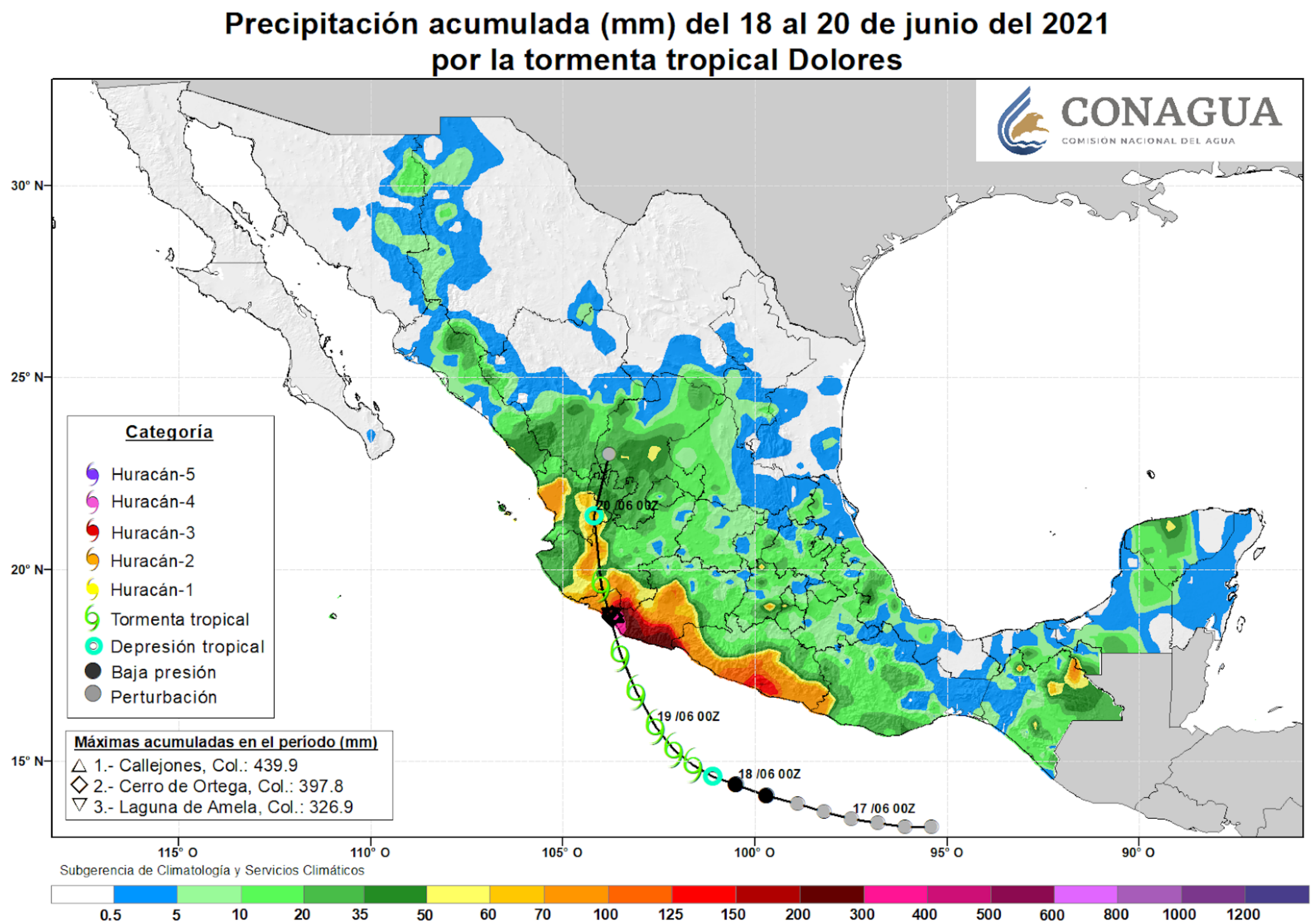

Figure 5. Total rainfall (mm) during the period 18–20 June 2021 when Dolores was a tropical cyclone. Map courtesy of Conagua – Comisión Nacional Del Agua.

Figure 6. Select images illustrating flooding and wind impacts associated with Dolores in Mexico. Images via El Comentario, The Navy of Mexico, Vivo Noticias, and Dependencia de la Secretaria de Infraestructura of Michoacán.

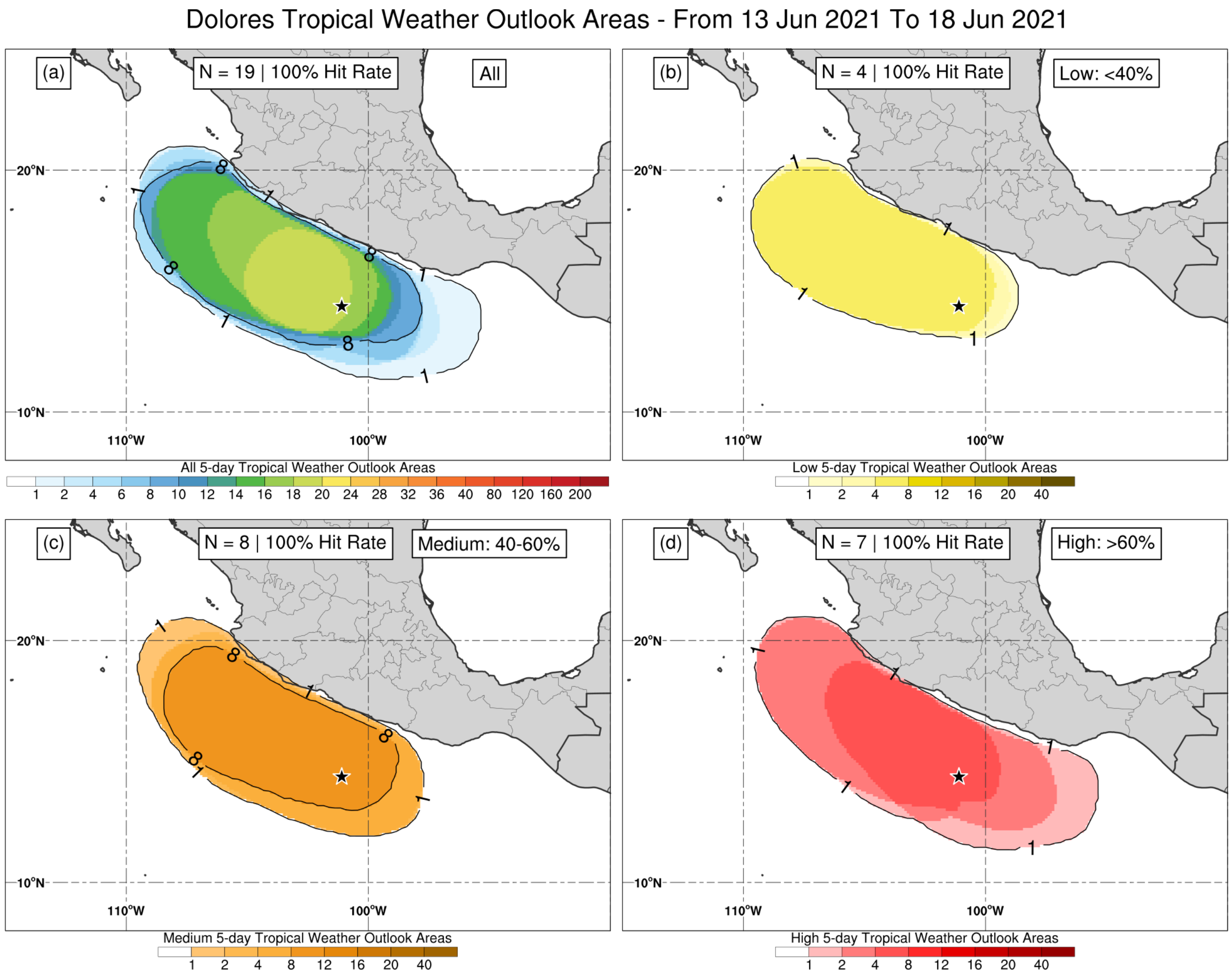

Figure 7. Composite of 5-day Tropical Weather Outlook areas associated with the disturbance that developed into Tropical Storm Dolores for (a) all probability areas (10–100%, multi-color shading), (b) low probability areas (< 40%, yellow shading), (c) medium probability areas (40–60%, orange shading), and (d) high probability areas (> 60%, red shading). The black star in each panel indicates the genesis location of Dolores. Black contours denote where at least one and eight outlook areas overlap.

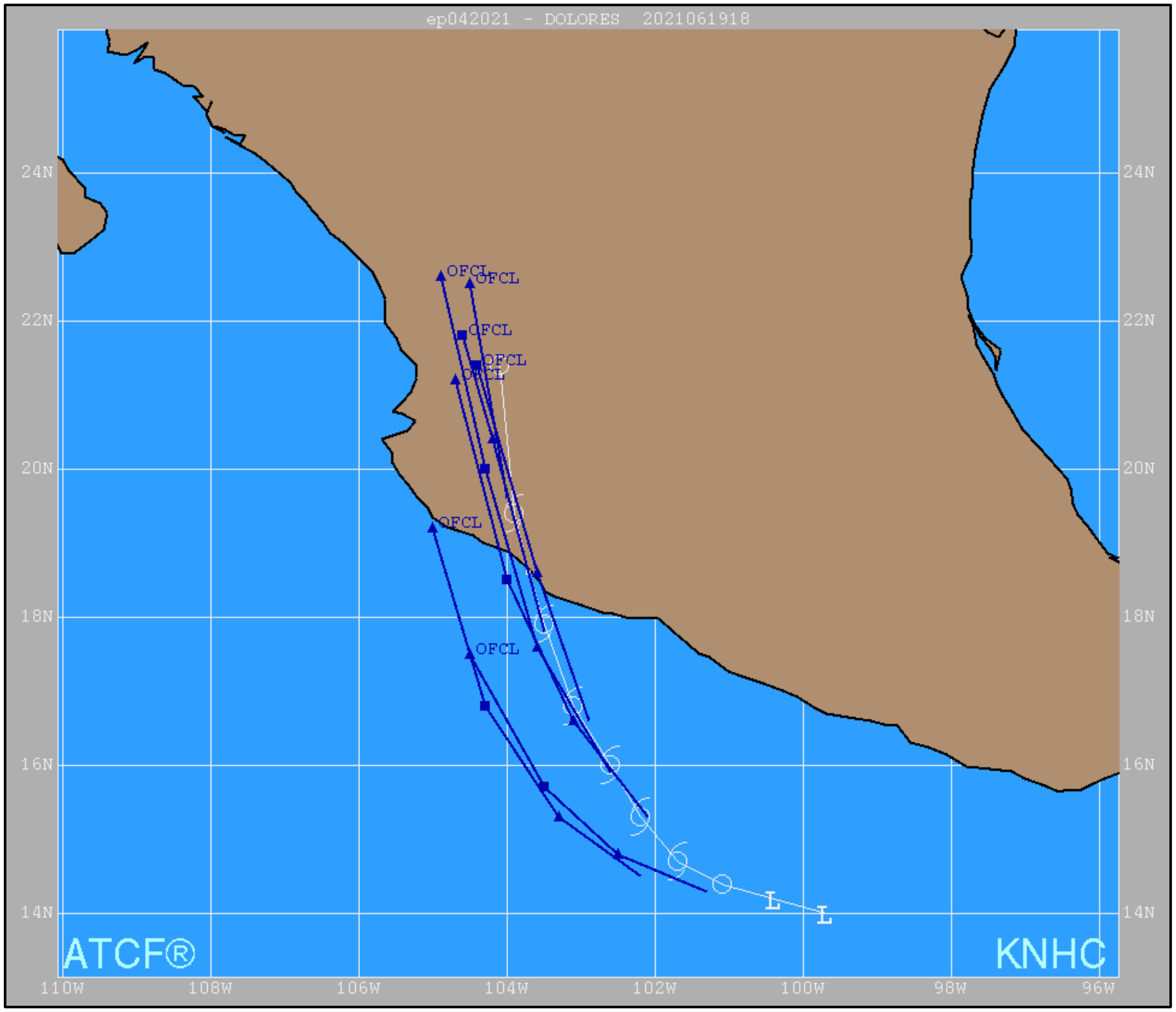

Figure 8. Selected official track forecasts (blue lines, with 0, 12, 24, 36 h positions indicated) for Tropical Storm Dolores, 18–20 June 2021. The best track is given by the white line with positions given at 6-h intervals.