NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

HURRICANE PAMELA

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10-13 October 2021

John P. Cangialosi
National Hurricane Center
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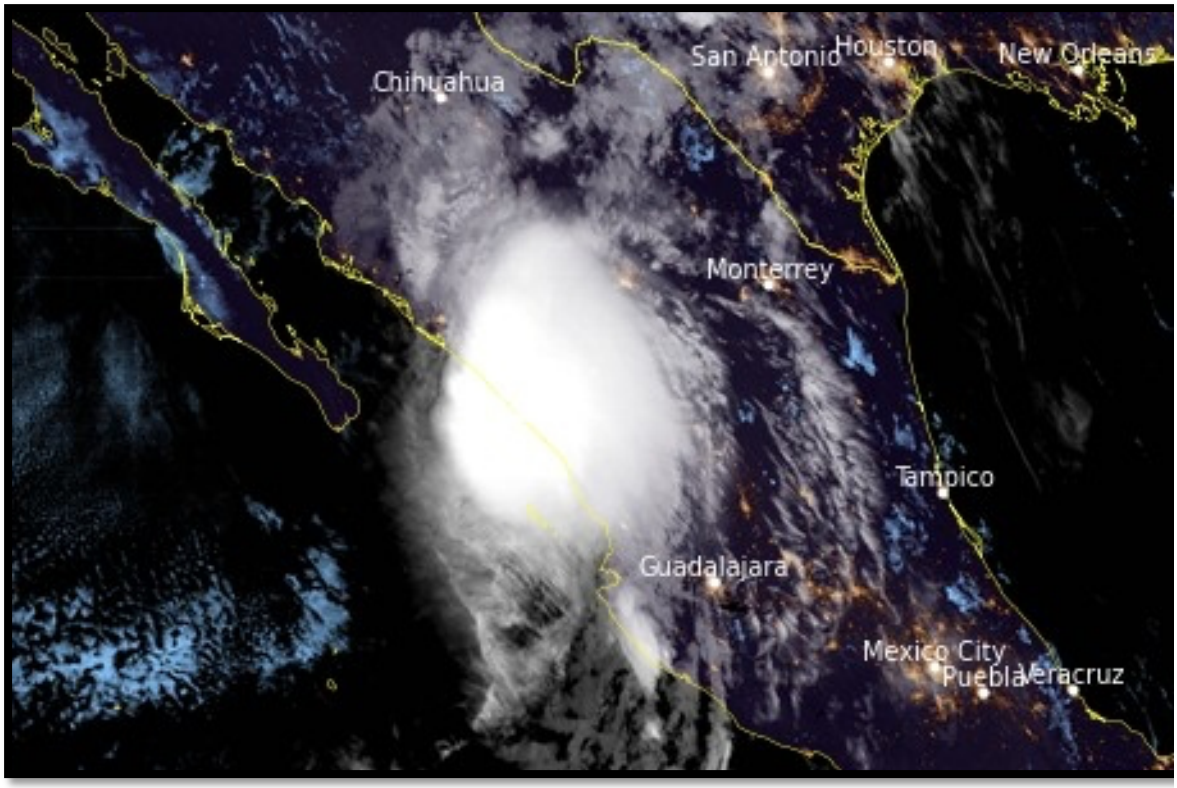

GOES-17 TRUE COLOR VISIBLE SATELLITE IMAGE OF HURRICANE PAMELA AROUND THE TIME IT MADE LANDFALL IN WEST-CENTRAL MEXICO. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Pamela was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that made landfall just north of Mazatlán, Mexico. The hurricane caused moderate damage along its track in west-central Mexico, and Pamela's remnants caused flooding across portions of central Texas.

Hurricane Pamela

10-13 OCTOBER 2021

SYNOPTIC HISTORY

Pamela originated from a tropical wave that departed the west coast of Africa late on 22 September. The wave produced disorganized showers and thunderstorms while it moved westward across the eastern and central tropical Atlantic during the next several days, but most of that activity weakened when it neared the Lesser Antilles by 1 October. Although deep convection was minimal along the wave as it moved across the Caribbean Sea, showers and thunderstorms began to increase again near the wave axis on 7 October when the system reached Central America. The wave emerged over the far eastern Pacific the next day, and showers and thunderstorms gradually consolidated as the disturbance continued westward south of the coasts of Central America and southern Mexico. Satellite images indicate that the system developed a well-defined center and enough organized deep convection to be classified as a tropical depression by 0600 UTC 10 October when it was located about 215 n mi southwest of Acapulco, 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 1[1].

After genesis, the cyclone moved west-northwestward at about 15 kt on the south side of a mid-level ridge. The depression gradually strengthened and became a tropical storm 6 h after formation, reaching an intensity of 45 kt by 0000 UTC 11 October. However, microwave images indicate that moderate northerly shear was affecting the storm with the low-level center remaining on the northern side of the main area of deep convection during that time. The tropical storm slowed down and turned northwestward later on 11 October as it reached the southwestern periphery of the ridge while Pamela continued to steadily strengthen. Pamela became a hurricane by 0600 UTC 12 October about 265 n mi south of the southern tip of the Baja California peninsula as it turned northward on the western side of the ridge. Later on 12 October, dry mid-level air entrained into the circulation of Pamela and deep convection eroded, leaving the low-level center exposed. Data from the Air Force Reserve Hurricane Hunters indicate that Pamela weakened back to a tropical storm by 1800 UTC that day as it turned north-northeastward when it was situated about 150 n mi south of the southern tip of the Baja California peninsula.

Deep convection increased and became more symmetric by early 13 October as Pamela turned northeastward within the flow on the southeastern side of a broad mid- to upper-level trough. A pair of scatterometer passes suggested that Pamela re-intensified into a hurricane by 0600 UTC that day when it was located about 110 n mi west-southwest of Mazatlán, Mexico. The hurricane maintained that intensity as it accelerated northeastward, and it made landfall around

[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.

1230 UTC 13 October (cover image) in a rural location between Mazatlán and Bahia Tempehuaya in west-central mainland Mexico.

After Pamela moved inland, the storm quickly weakened due to the rugged terrain, drier air, and an increase in shear. Pamela became a tropical storm within the next 6 h and dissipated shortly before 0000 UTC 14 October over northern Mexico. Abundant moisture associated with the remnants of Pamela spread across portions of south-central U.S. later that day.

METEOROLOGICAL STATISTICS

Observations in Pamela (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 (CIMSS). 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 Pamela. Aircraft observations include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from one flight of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command.

There were no ship or buoy reports of tropical-storm-force winds associated with Pamela.

Winds and Pressure

Pamela reached a peak intensity of 65 kt twice during its lifetime. The first peak at 0600 and 1200 UTC 12 October is based on subjective and objective Dvorak estimates from TAFB, SAB, and CIMSS that ranged from 57 to 77 kt during that time frame. The second 65-kt peak from 0600 UTC 13 October until landfall at 1230 UTC that day is based on a pair of ASCAT passes just before 0600 UTC that showed maximum winds around 55 kt. Since the instrument does not have adequate resolution to resolve the inner core and because the satellite presentation of the system improved around and after 0600 UTC 13 October, it is estimated that Pamela achieved hurricane status again prior to landfall.

The estimated minimum pressure of 987 mb at 1200 UTC 12 October and 0600 UTC 13 October is based on the Knaff-Zehr-Courtney and Dvorak pressure-wind relationships. The landfall pressure of 989 mb is based on in situ pressure data of 990.8 mb just south of the center at 1208 and 1246 UTC 13 October by Josh Morgerman of the iCyclone storm chasing team, which was located in Marmol de Salcido, Sinaloa, Mexico.

Pamela made landfall in a fairly remote area with limited observations, and none of the observing sites reported sustained tropical-storm-force winds. The highest reported wind speed was 29 kt with a gust to 51 kt at Isla Maria Madre at 0800 UTC 13 October. A sustained wind of 27 kt with a gust to 40 kt was reported at Mazatlán International Airport at 1342 UTC 13 October.

A minimum pressure of 1000 mb was recorded at the airport, but the iCyclone chase team also in Mazatlán measured a minimum pressure of 996.3 mb at 1212 UTC 13 October.

Storm Surge

No official storm surge heights are available. However, reports from the media and the iCyclone chasing team indicate that battering waves occurred in the landfall region in the Mexican state of Sinaloa. The surf caused minor to moderate damage along the coastline.

Rainfall

Pamela is estimated to have produced a widespread area of 4 to 8 inches of rain across the Mexican states of Sinaloa, western Durango, and northern Nayarit, with isolated maxima of up to 12 inches on 13 October. Lower amounts of less than 3 inches occurred over the southern portion of Baja California Sur.

Abundant tropical moisture associated with the remnants of Pamela and a cold front combined to cause a large area of 3 to 6 inches of rain across portions of central Texas on 13–14 October (Fig. 6). The highest reported rainfall total was in Gonzales, where 9.9 inches fell during that time period. Lower amounts of rain occurred farther north across Oklahoma and southwestern Arkansas, but there were a few spots of 3 or 4 inches reported there.

CASUALTY AND DAMAGE STATISTICS

There were no direct fatalities associated with Pamela in Mexico. However, media reports indicate that dozens of people were trapped in their homes near Mazatlán due to flood waters and associated debris. Pamela caused widespread flooding and moderate wind damage in the Mexican states of Sinaloa, western Durango, and northern Nayarit, where numerous trees were uprooted and streets flooded. In Mazatlán, several stores and restaurants suffered damage (Figs. 4 and 5). The iCyclone chase team noted in their final report that many streets in Mazatlán were flooded, and the city's waterfront promenade was littered with debris. A damage estimate is unknown at the time of this report.

In Texas, two people lost their lives from the remnants of the hurricane. A 52-year-old woman and 5-year-old girl died when the separate vehicles that they were traveling in went through flood waters on a bridge that caused them to fall into the Martinez Creek outside of San Antonio. Four other children and a man were rescued from the same two vehicles.

FORECAST AND WARNING CRITIQUE

The genesis of Hurricane Pamela was fairly well forecast. 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 disturbance that became Pamela was first mentioned in the TWO with a low chance (<40%) of formation during the next 5 days 126 h prior to genesis. The 5-day probabilities reached the medium (40–60%) and high categories (>60%) 102 h and 72 h prior to when Pamela formed, respectively. Regarding the 2-day genesis probabilities, a low chance of genesis was shown 72 h, medium chance 42 h, and high chance 30 h before Pamela developed.

A verification of NHC official track forecasts for Pamela is given in Table 3a. The official forecast (OFCL) mean errors were near their 5-yr means from 12 to 48 h, but well above the means at 60 and 72 h, albeit for a small number of verifying forecasts. The OCD5 errors were well above their 5-yr means at all forecast times, indicating that Pamela's track was more difficult to predict than average. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The OFCL track forecasts performed fairly well relative to the guidance, but they were outperformed at all forecast times by EMXI, and the consensus aids HCCA and TVCX. The main source of error was that the forecasts were too slow; in particular the first few forecasts did not anticipate how much Pamela would accelerate around the landfall time.

A verification of NHC official intensity forecasts for Pamela is given in Table 4a. The official NHC intensity forecast errors were well above the 5-yr means, and were not skillful with errors higher than OCD5 at all verifying forecast times. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official forecasts were quite poor for Pamela, with DSHP, LGEM, and IVCN outperforming NHC at most forecast times. The official forecasts and many of the standard intensity models had a significant high bias (Fig. 7), as many of the NHC and model forecasts predicted Pamela to be a category 2 or category 3 hurricane before it reached the coast of Mexico. However, the environment turned out to not be as favorable as expected, as dry air and mid-level shear interrupted the intensification trend of Pamela, leading to large errors and biases.

Coastal watches and warnings for Pamela are shown in Table 5.

Table 1. Best track for Hurricane Pamela, 10–13 October 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
10 / 0600	14.1	102.4	1007	30	tropical depression
10 / 1200	14.6	103.8	1006	35	tropical storm
10 / 1800	15.2	105.2	1004	40	"
11 / 0000	15.7	106.3	1002	45	"
11 / 0600	16.2	107.3	1000	45	"
11 / 1200	16.6	107.9	998	50	"
11 / 1800	17.0	108.4	995	55	"
12 / 0000	17.6	108.8	991	60	"
12 / 0600	18.6	109.1	988	65	hurricane
12 / 1200	19.6	109.3	987	65	"
12 / 1800	20.6	109.3	989	60	tropical storm
13 / 0000	21.5	108.9	989	60	"
13 / 0600	22.3	108.2	987	65	hurricane
13 / 1200	23.6	106.8	988	65	"
13 / 1230	23.7	106.7	989	65	"
13 / 1800	25.1	104.8	999	40	tropical storm
14 / 0000					dissipated
12 / 1200	19.6	109.3	987	65	maximum wind speed and minimum pressure
13 / 1230	23.7	106.7	989	65	Landfall just north of Mazatlan, Mexico

Table 2. Number of hours in advance of formation of Pamela 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%)	72	126
Medium (40%-60%)	42	102
High (>60%)	30	72

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Pamela, 10–13 October 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	22.6	**31.2**	**33.9**	55.7	97.1	161.9		
OCD5	52.7	113.9	202.2	303.7	430.1	540.9		
Forecasts	13	11	9	7	5	3	0	0
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 Hurricane Pamela, 10–13 October 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	19.9	31.0	36.2	50.4	91.5	205.8		
OCD5	50.0	116.3	220.7	350.6	522.5	701.5		
GFSI	21.5	42.5	62.5	82.6	162.3	288.0		
HWFI	26.2	43.7	51.3	72.9	101.2	256.1		
HMNI	28.8	44.0	66.5	78.5	129.9	235.1		
EGRI	21.1	32.8	51.7	64.4	100.4	227.6		
EMXI	**18.4**	**24.6**	**28.9**	**42.5**	**46.6**	**136.3**		
NVGI	29.4	45.1	40.8	**27.0**	**36.7**	**62.2**		
CTCI	20.5	38.3	47.4	60.1	103.4	211.4		
CMCI	20.4	34.2	70.3	108.6	130.3	**128.6**		
AEMI	20.5	38.0	53.3	55.8	107.1	**186.7**		
HCCA	**18.2**	**28.3**	**35.5**	**30.2**	**56.0**	**157.3**		
TVCE	**19.7**	31.3	38.8	**46.5**	**91.0**	220.4		
TVCX	**18.8**	**28.0**	**33.2**	**37.4**	**73.0**	**194.8**		
TVDG	**18.8**	**29.3**	37.0	**37.6**	**85.2**	209.0		
TABS	28.4	37.8	63.1	123.4	227.8	395.7		
TABM	26.8	41.3	50.5	64.1	157.2	333.7		
TABD	26.0	62.1	79.3	78.4	91.5	207.0		
Forecasts	9	7	6	5	3	1	0	0

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Pamela, 10–13 October 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	7.7	10.5	18.3	20.7	29.0	38.3		
OCD5	6.2	5.1	8.0	12.0	12.0	15.7		
Forecasts	13	11	9	7	5	3	0	0
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 Hurricane Pamela, 10–13 October 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	7.1	9.0	19.4	20.7	29.0	38.3		
OCD5	**6.4**	**5.3**	**7.1**	**12.0**	**12.0**	**15.7**		
HWFI	7.4	11.7	**13.9**	**20.4**	**26.4**	40.3		
HMNI	**6.1**	9.8	**14.6**	**18.7**	**26.4**	**35.3**		
CTCI	**6.5**	9.2	20.1	31.6	33.2	40.7		
DSHP	**6.7**	9.3	**13.5**	**16.7**	**22.2**	**26.7**		
LGEM	7.3	**7.7**	**8.4**	**10.1**	**13.2**	**16.0**		
HCCA	8.7	15.9	24.6	31.7	37.8	43.7		
IVCN	**6.4**	**8.6**	**13.6**	**19.4**	**24.4**	**32.3**		
IVDR	**6.4**	9.0	**14.0**	20.7	**26.8**	**35.0**		
GFSI	7.4	**8.4**	**12.2**	**17.3**	31.0	38.7		
EMXI	7.7	9.7	**14.4**	**18.6**	**11.4**	**14.3**		
Forecasts	12	10	8	7	5	3	0	0

Table 5. Wind watch and warning summary for Hurricane Pamela, 10–13 October 2021.

Date/Time (UTC)	Action	Location
11 / 1500	Hurricane Watch issued	Bahia Tempehuaya to Escuiapa
11 / 1500	Tropical Storm Watch issued	Bahia Tempehuaya to Altata and from Escuiapa to San Blas, including Isla Marias
11 / 1500	Tropical Storm Watch issued	Baja California from Los Barilles to Cabo San Lucas
12 / 0000	Hurricane Watch changed to Hurricane Warning	Bahia Tempehuaya to Escuiapa
12 / 0000	Tropical Storm Warning issued	Bahia Tempehuaya to Altata and from Escuiapa to Cabo Corrientes, including Isla Marias
13 / 0300	Tropical Storm Watch discontinued	Baja California from Los Barilles to Cabo San Lucas
13 / 1500	Hurricane Warning changed to Tropical Storm Warning	Bahia Tempehuaya to Escuiapa
13 / 1800	Tropical Storm Warning discontinued	All

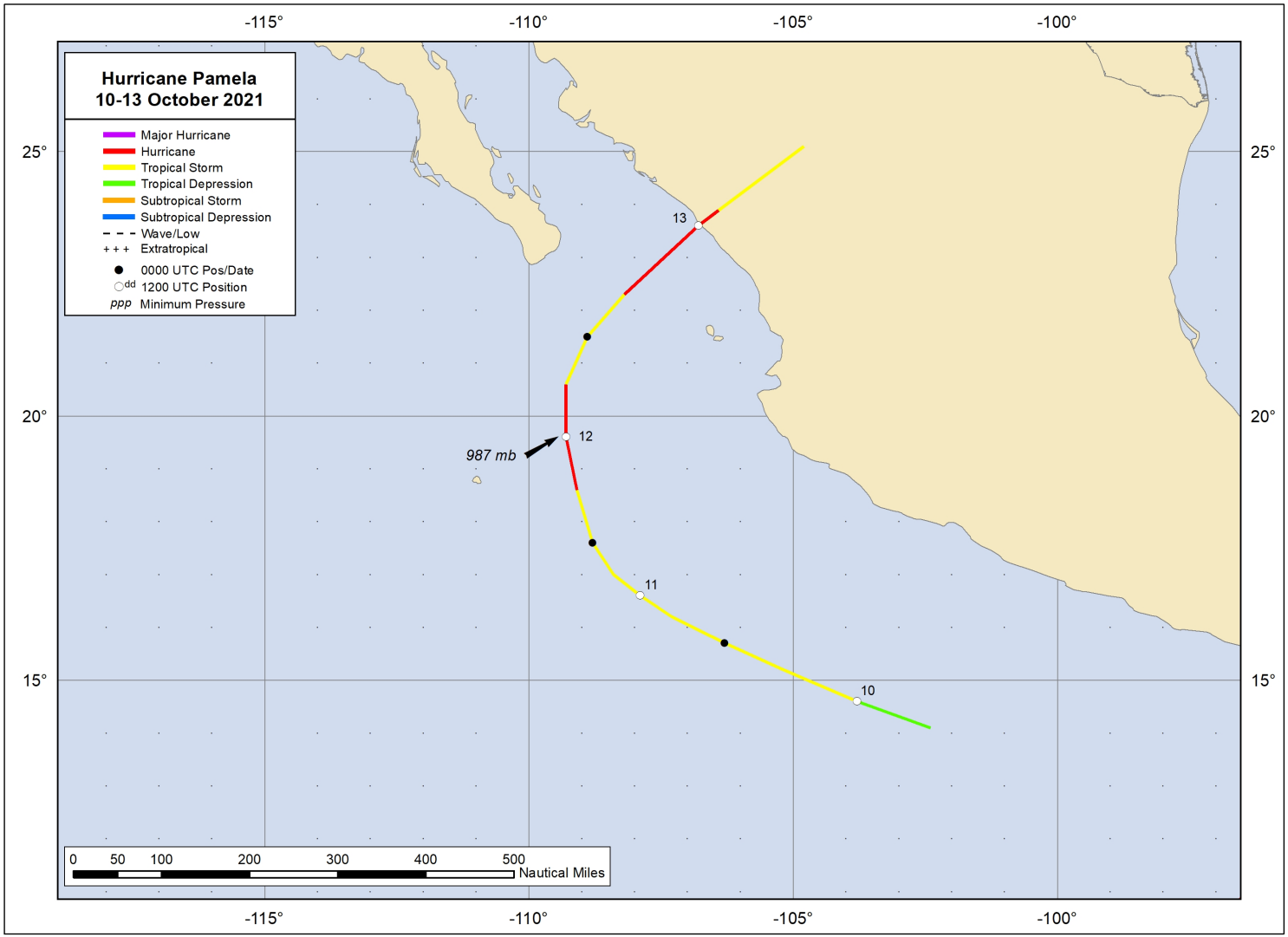

Figure 1. Best track positions for Hurricane Pamela, 10–13 October 2021.

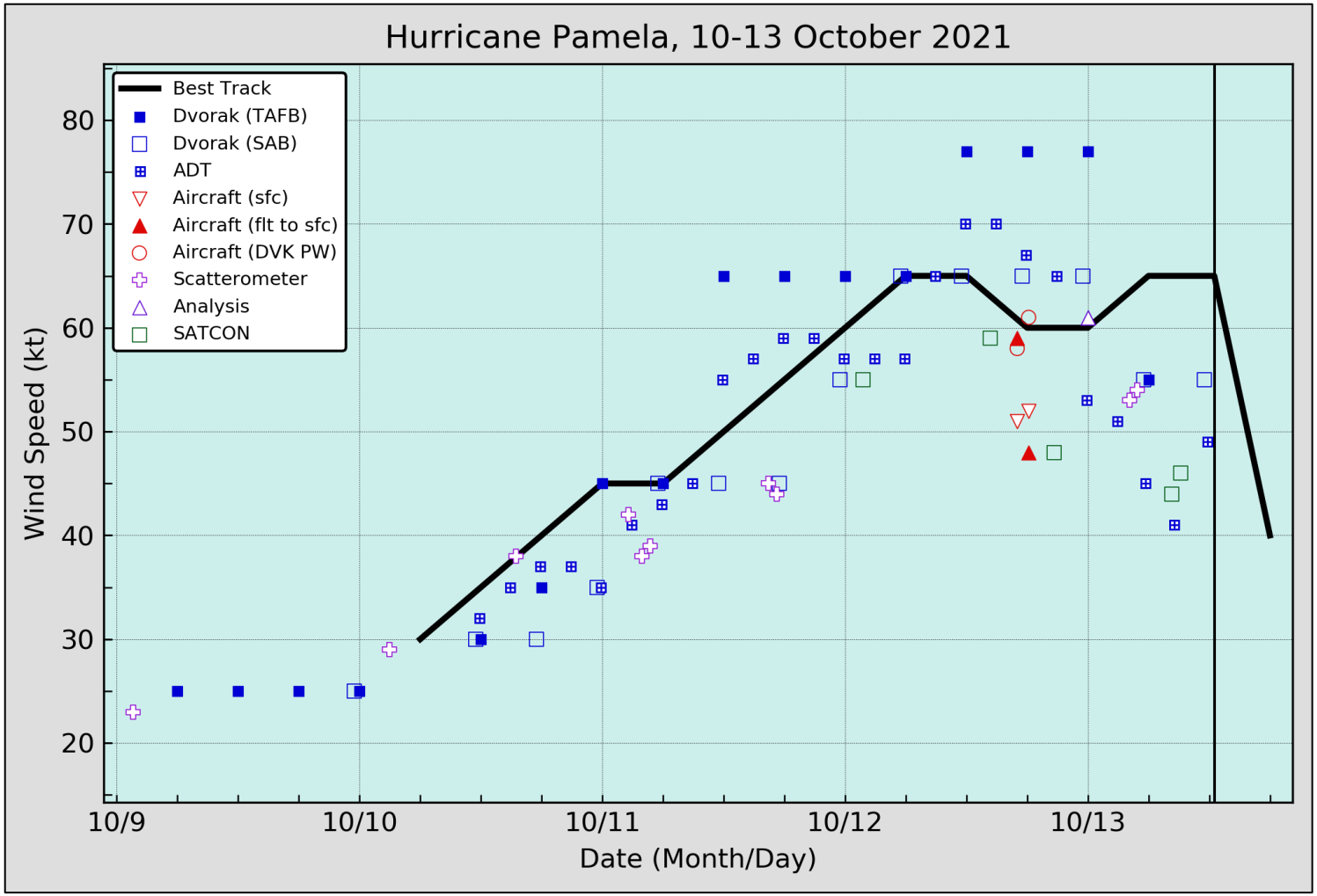

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Pamela, 10–13 October 2021. Aircraft observations have been adjusted for elevation using 90% adjustment factors for observations from 700 mb. Advanced Dvorak Technique estimates represent the 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.

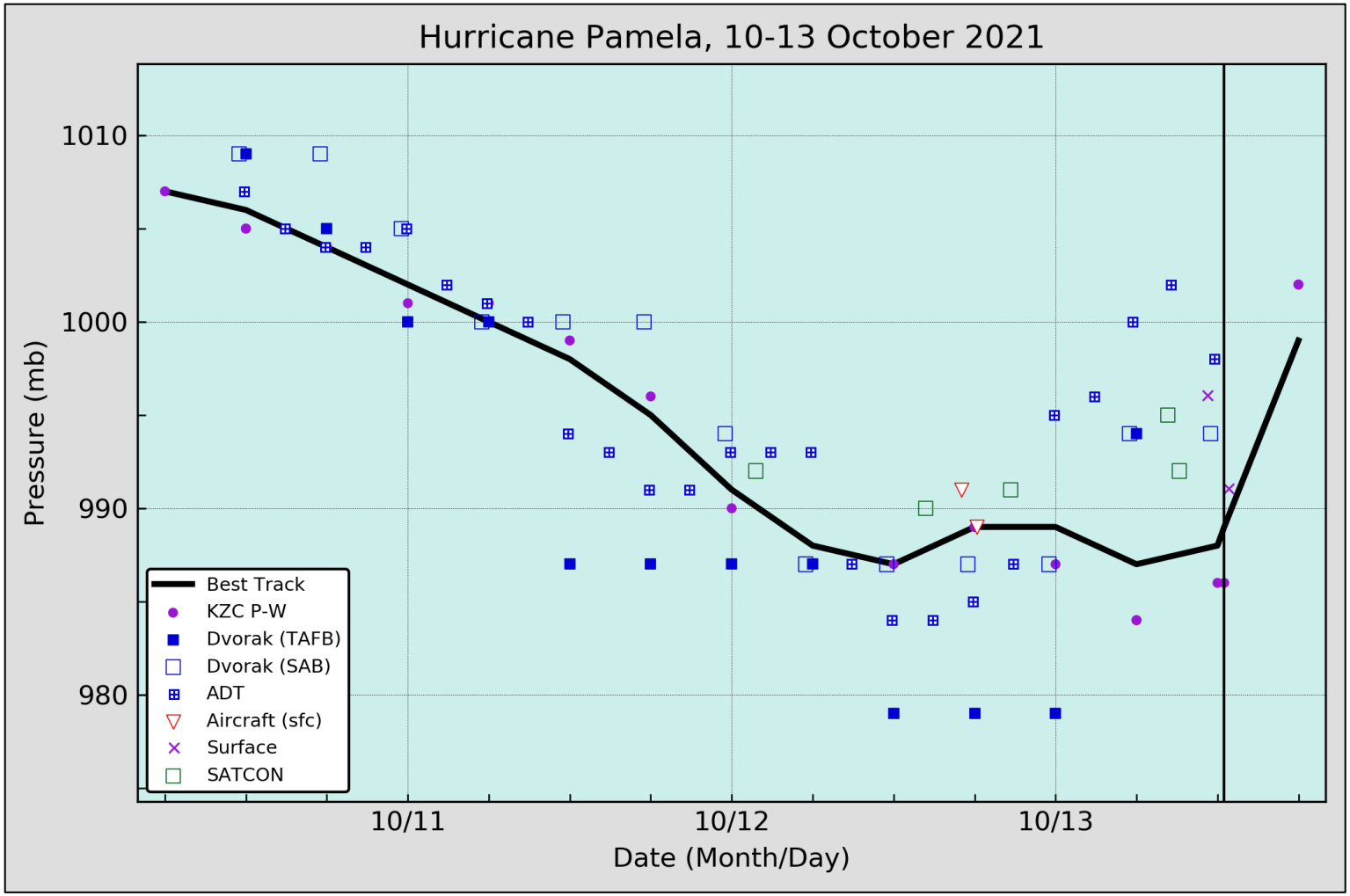

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Pamela, 10–13 October 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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. Wind damage in a commercial area in Mazatlán, Mexico. Courtesy of the Associated Press.

Figure 5. Image of damage to businesses in Mazatlán, Mexico. Courtesy of iCyclone.

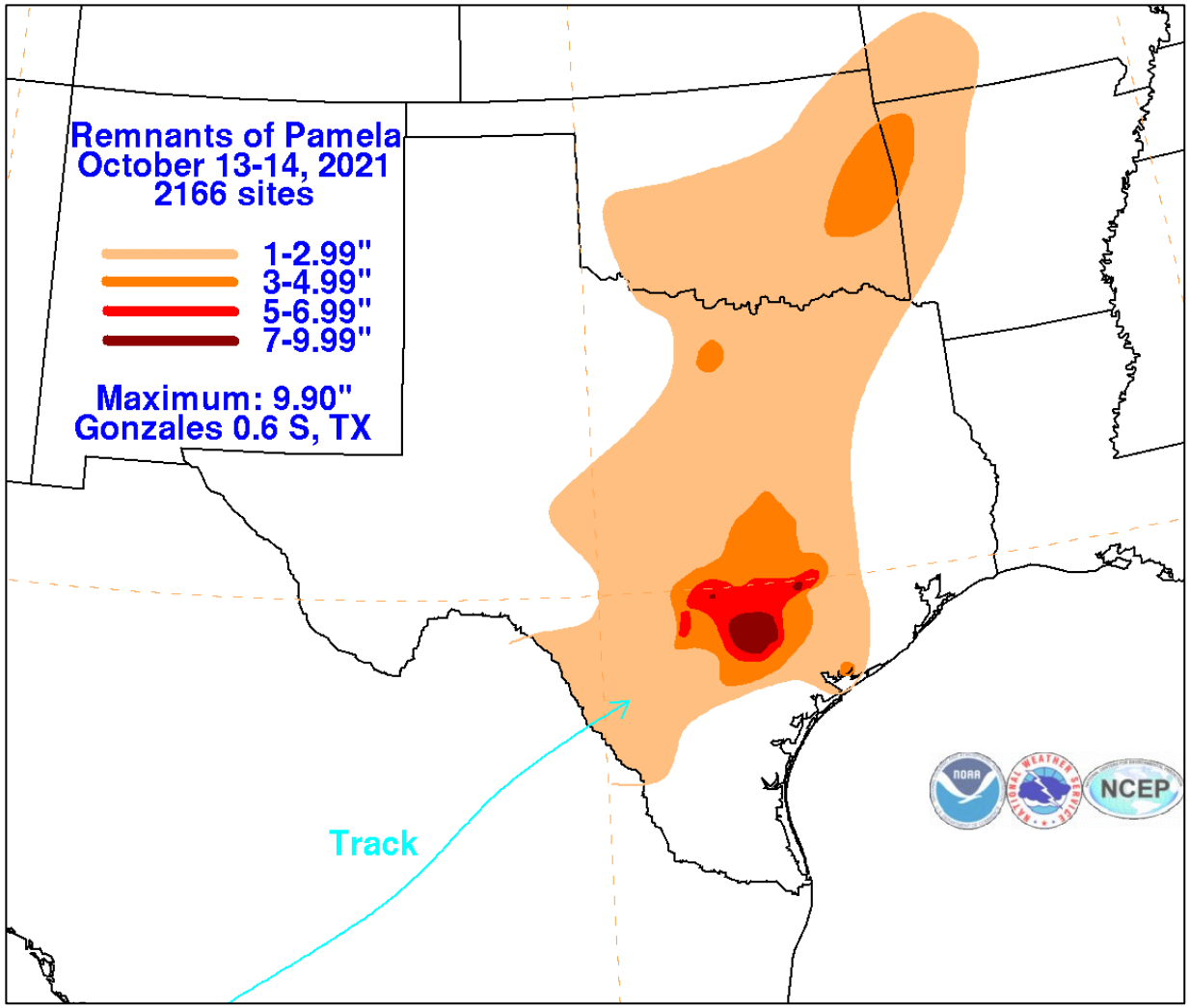

Figure 6. Total rainfall associated with the remnants of Pamela over the south-central U.S. Image courtesy of the Weather Prediction Center.

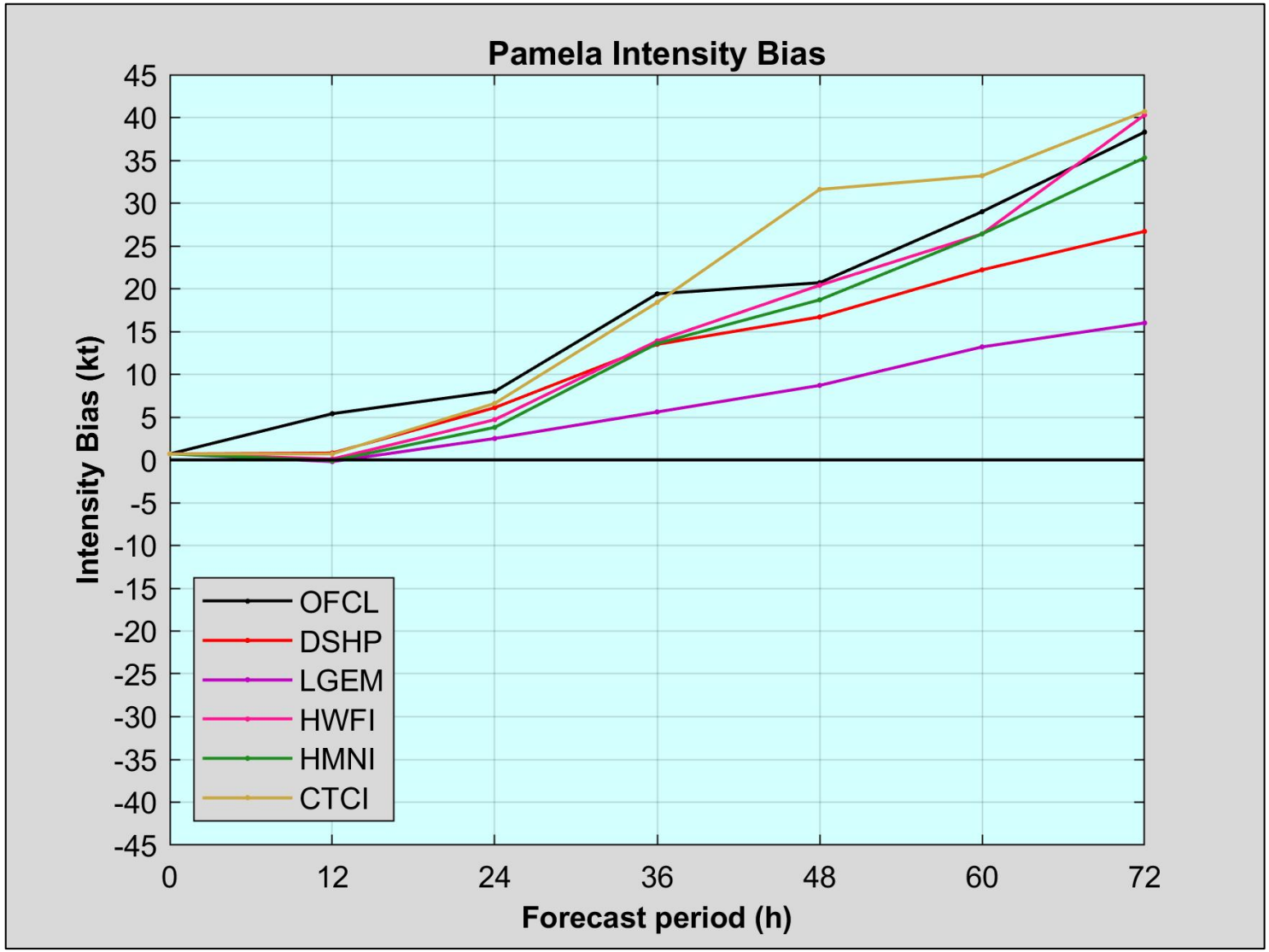

Figure 7. Intensity forecast biases (kt) of the official forecasts (OFCL) and selected individual models for Hurricane Pamela, 10–13 October 2021.