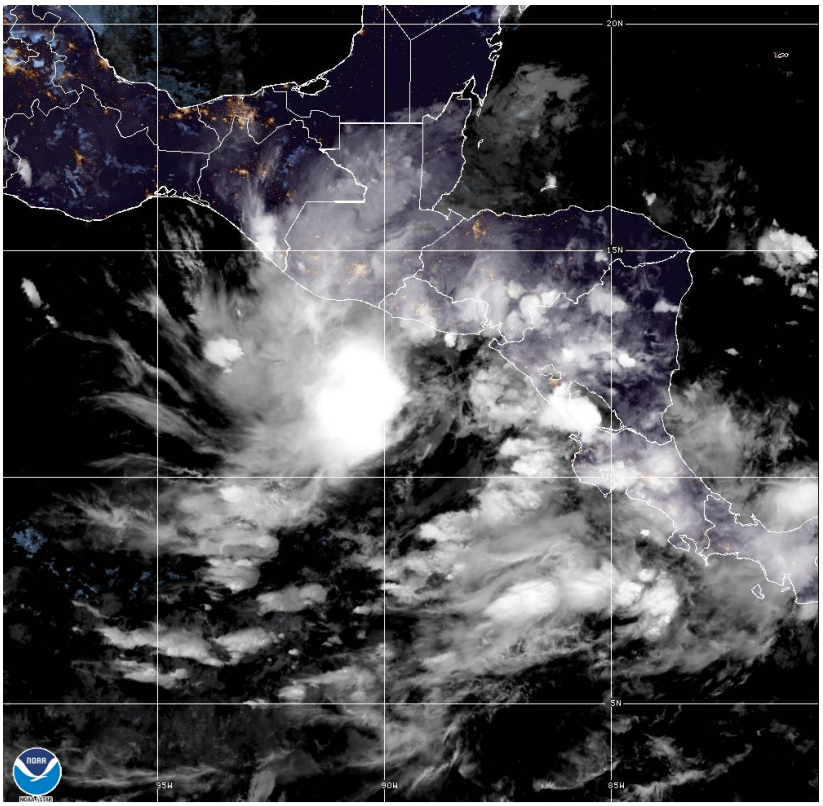
NATIONAL HURRICANE CENTER
TROPICAL CYCLONE REPORT

TROPICAL STORM PILAR

(EP192023)

28 October – 5 November 2023

Eric Blake
National Hurricane Center
8 March 2024



GOES-16 GEOCOLOR IMAGE OF TROPICAL STORM PILAR AT 0000 UTC 1 NOVEMBER 2023 NEAR PEAK INTENSITY. IMAGE COURTESY OF NOAA/NESDIS STAR.

Pilar was a tropical storm that took an unusual east-northeastward track, approaching Central America from the west, but then turned westward and moved away from land without making landfall. Still, heavy rains from the tropical storm overspread Central America, and 4 deaths were noted from flooding.

Tropical Storm Pilar

28 OCTOBER – 5 NOVEMBER 2023

SYNOPTIC HISTORY

Pilar formed from the remnants of Atlantic Tropical Depression Twenty-One. After the system dissipated over Nicaragua on 24 October, the wave moved slowly westward. A broad low re-formed over the far eastern Pacific on 25 October, but its development was slowed over the next few days by persistent easterly shear. The low was close to becoming well defined on 27 October, with a mid-level circulation noted and plentiful convection, but surface observations indicated it was still broad. After another burst of central convection overnight, scatterometer data indicate that the circulation became well defined enough to be considered a tropical depression near 1200 UTC 28 October, about 250 n mi southwest of San Salvador, El Salvador. Little motion occurred for over a day as ridging to the north of the system weakened and steering currents collapsed. However, by late on 29 October, the depression started moving slowly east-northeastward due to a deep-layer trough over the northwestern Caribbean Sea and an enhanced equatorial ridge to the south. This pattern led to a slight reduction in shear and allowed deep convection to form over the center, which tightened the system's low-level circulation. The depression is estimated to have become Tropical Storm Pilar near 0000 UTC 30 October based on scatterometer data near 35 kt and satellite estimates while centered about 220 n mi west-southwest of San Salvador. The "best track" chart of Pilar'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].

Pilar erratically intensified during the next couple of days, tempered by moderate easterly wind shear. The tropical storm reached a peak intensity of 55 kt, as suggested by Dvorak estimates and scatterometer data, around 0000-0600 UTC 1 November about 80 n mi offshore of El Salvador. However, the synoptic pattern around Pilar was quickly changing with a strong cold front approaching from the northwestern Caribbean Sea. This feature and its associated mid-level ridge caused the tropical storm to turn sharply northward and westward, remaining offshore of Central America. An influx of drier air also caused Pilar to weaken some, though it was tempered by its faster forward speed and increased synoptic pressure gradient. Pilar reached a brief second peak intensity of 55 kt while interacting with a larger-scale gap wind flow, as shown by high-resolution scatterometer data, while moving quickly west-southwestward a few hundred miles south-southwest of the Gulf of Tehuantepec. Another intrusion of drier air caused the system to weaken on 3 November, though Pilar maintained an intensity of about 40 kt the next day while remaining in a low-to-moderate shear environment, over warm SSTs and in the

[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.

marginally humid airmass. The tropical storm resumed its decay on 5 November due to an increase in southwesterly shear, and the low- and mid-level circulations detached by midday. Pilar lost all of its deep convection by 1800 UTC that day, marking its transition to a post-tropical low, and it weakened below gale-force 6 h later. The remnant low moved westward on 6 November and northwestward on 7 November, with satellite imagery showing the low opening up into a trough of low pressure by 1800 UTC 7 November, when it was located several hundred miles southwest of the southern tip of Baja California Sur.

METEOROLOGICAL STATISTICS

Observations in Pilar (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 Pilar.

Selected surface observations from land stations and data buoys are given in Table 2, and ship reports of winds of tropical storm force associated with Pilar are given in Table 3.

Winds and Pressure

Pilar's first peak intensity of 55 kt was based on SAB Dvorak estimates, with supporting data from scatterometer and a Synthetic Aperture Radar (SAR) pass. High-resolution (UHR) ASCAT data from 1605 UTC 31 October (Fig. 4) provided by NOAA NESDIS during the post-analysis suggests Pilar's winds were in the 50–55 kt range. While there is some uncertainty about the reliability of the UHR data, the improvement on conventional satellite data from the time of the ASCAT pass to 0000 UTC 1 November suggested that 55 kt was best supported by the data. Additionally, a SAR pass at 0011 UTC November 1 also showed winds of at least 55 kt in all 4 quadrants of the storm. Pilar's second 55-kt peak intensity on 2 November was based on ASCAT data, with low-resolution data supporting at least 50 kt, and high-resolution ASCAT data of up to 55-kt winds (Fig. 4). Note this is higher than conventional satellite estimates, probably because of the enhanced gradient on the northern side of the storm due to a concurrent Gulf of Tehuantepec gap wind event. The estimated minimum pressure of 995 mb was based on the Knaff-Zehr-Courtney pressure wind relationship.

While there were no sustained tropical-storm-force winds recorded over land, a pair of observation sites in El Salvador had wind gusts over 50 kt (Table 2), and it is probable that some sustained tropical-storm-force winds were recorded at higher elevations, likely from a combination of Pilar and a strong cold front.

Rainfall and Flooding

Pilar brought a widespread area of 3 to 6 inches of rain to El Salvador, with maximum totals near 9 inches across the southeastern portion of that country (Fig. 5). The maximum rainfall (8.89 inches or 225.9 mm) was reported near Beneficio La Carrera. This rainfall caused many mud slides across El Salvador and flooded rivers. Very heavy rains also occurred in Honduras, but no totals are available.

CASUALTY AND DAMAGE STATISTICS

There were 4 direct[2] deaths in association with Pilar, all from flooding. Three deaths were noted in El Salvador and one in Honduras, with three other injuries reported in Honduras.

Heavy rainfall from Pilar caused flooding in portions of Guatemala, El Salvador and Honduras. Media reports indicate that many rivers flooded, which displaced hundreds of families from their homes, and caused notable crop damage. In El Salvador, over 100 trees were knocked down, presumably due to the saturated soils making the trees susceptible to the gusty winds, and about a couple of dozen homes were damaged.

In Honduras, the government reported that thousands of people were evacuated, and about 700 homes were flooded from Pilar, with 5 destroyed, along with roads washed away and bridges damaged. However, most of these impacts were actually related to the strong cold front, and Pilar's moisture seemingly played a small role (most of the damage was from 3 – 5 November, well after Pilar departed). No official monetary estimates of the damage are available, although the firm AON estimated a total loss of $45 million (USD) from the storm.

FORECAST AND WARNING CRITIQUE

The genesis of Pilar was well anticipated (Table 4). The potential for tropical cyclone development was first mentioned in the Tropical Weather Outlook (TWO) about 108 h before Pilar became a tropical cyclone, with good lead time considering that Atlantic Tropical Depression Twenty-One had not yet dissipated. The chances rose into the high (>60%) category for the 7-day forecast about 3 days before genesis. The system entered the 2-day outlook in the low (< 40%) tercile a little over 3 days before formation, and was in the high category for almost 2 full days before genesis. The location of genesis was also well forecast as all of the 7-day Graphical TWOs issued prior to formation captured Pilar's genesis location (Fig. 6).

[2] 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.

A verification of NHC official track forecasts for Pilar is given in Table 5a. The NHC track forecast errors were greater than the 5-yr means at all times, perhaps not surprising due to the unusual track and high OCD5 errors (which also suggest that this was a difficult storm to forecast). A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. There were some outstanding track models for Pilar, including the ECMWF and UKMET models. The HAFS model suite had one of its poorer track performances of the season, especially HAFS-B (HFBI).

A verification of NHC official intensity forecasts for Pilar is given in Table 6a. Contrary to track, the NHC official intensity forecast errors were lower than the 5-year means at all time periods, though the OCD5 errors were not all lower than the means. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. Overall, the NHC forecast outperformed the intensity aids for a majority of the forecast times, correctly predicting that the environment would not allow Pilar to become a hurricane. Interestingly, some of the poorer track models, like the HAFS suite, had some of the lowest intensity errors for this storm, while the HWRF/HMON models, which had a good track performance, had high intensity errors.

Coastal watches and warnings associated with Pilar are given in Table 7. Tropical Storm Watches were issued for the Pacific coasts of El Salvador, Honduras and a portion of Nicaragua – a rare occurrence in the historical record.

Table 1. Best track for Tropical Storm Pilar, 28 October – 5 November 2023.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 1200	10.4	92.6	1005	30	tropical depression
28 / 1800	10.2	92.6	1005	30	"
29 / 0000	10.4	92.8	1004	30	"
29 / 0600	10.7	92.9	1004	30	"
29 / 1200	10.7	92.7	1004	30	"
29 / 1800	10.7	92.6	1004	30	"
30 / 0000	10.8	92.3	1003	35	tropical storm
30 / 0600	10.9	92.0	1003	35	"
30 / 1200	11.0	91.7	1002	40	"
30 / 1800	11.1	91.4	1000	45	"
31 / 0000	11.2	91.1	999	45	"
31 / 0600	11.2	90.6	999	45	"
31 / 1200	11.2	90.2	999	45	"
31 / 1800	11.4	89.8	998	50	"
01 / 0000	11.7	89.4	995	55	"
01 / 0600	12.1	89.6	995	55	"
01 / 1200	12.4	90.1	997	50	"
01 / 1800	12.4	91.1	999	45	"
02 / 0000	12.4	92.1	999	45	"
02 / 0600	12.4	93.3	999	45	"
02 / 1200	12.2	94.6	998	50	"
02 / 1800	11.6	96.3	996	55	"
03 / 0000	11.0	98.2	998	50	"
03 / 0600	10.6	100.2	1000	45	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
03 / 1200	10.3	102.2	1000	45	"
03 / 1800	10.2	104.0	1002	40	"
04 / 0000	10.1	105.7	1002	40	"
04 / 0600	10.1	107.1	1002	40	"
04 / 1200	10.1	108.5	1002	40	"
04 / 1800	10.2	109.8	1002	40	"
05 / 0000	10.3	111.0	1002	40	"
05 / 0600	10.4	112.0	1002	40	"
05 / 1200	10.5	113.0	1003	40	"
05 / 1800	10.5	113.9	1004	35	low
06 / 0000	10.6	114.4	1005	30	"
06 / 0600	10.6	114.7	1006	25	"
06 / 1200	10.6	115.0	1006	25	"
06 / 1800	10.7	115.3	1007	25	"
07 / 0000	11.0	116.2	1007	25	"
07 / 0600	12.1	117.0	1007	25	"
07 / 1200	13.4	117.7	1007	25	"
07 / 1800					dissipated
01 / 0000	11.7	89.4	995	55	minimum pressure and max winds

Table 2. Selected surface observations for Tropical Storm Pilar, 28 October – 5 November 2023, all in El Salvador.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)	Gust (kt)	
La Unión Airport (MSLU)		1008				6.58
La Aramuaca Airport, San Miguel (MSAC)		1004				1.97
El Salvador Intl Airport (MSLP)		1007	1/0400	25	31	3.99
El Imposible					53	
Puerto Parada					61	
Beneficio La Carrera						8.89
Volcán de San Miguel						8.41
La Cañada La Unión						7.70
Perquín Morazán						7.02
Chiltiupán, La Libertad						5.72
Zoologico, San Salvador						5.64

[a] Date/time is for sustained wind when both sustained and gust are listed.

Table 3. Selected ship reports with winds of at least 34 kt for Tropical Storm Pilar, 28 October – 5 November 2023.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/ speed (kt)	Pressure (mb)
01 / 0900	D5HF5	15.1	95.6	050 / 35	1014.3
02 / 0600	VRMC7	14.3	94.3	030 / 40	1010.0
02 / 0700	VRMC7	14.3	94.3	010 / 40	1010.0
02 / 0800	VRMC7	14.4	94.4	360 / 43	1010.0
02 / 1800	VRMC7	14.9	95.9	050 / 42	1012.0
02 / 1900	VRMC7	14.9	95.9	050 / 42	1011.0
02 / 2000	VRMC7	14.9	96.1	050 / 40	1011.0
02 / 2100	VRMC7	14.9	96.3	050 / 35	1010.0
03 / 0100	5LDS2	14.4	94.8	050 / 38	1018.6

Table 4. 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	**168-Hour Outlook**
Low (<40%)	78	108
Medium (40%-60%)	60	84
High (>60%)	42	72

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Pilar, 28 October – 5 November 2023. 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	24.4	39.9	51.8	75.2	109.1	144.6	232.2	306.0
OCD5	46.2	111.8	203.6	318.7	449.2	575.5	762.5	779.2
Forecasts	30	28	26	24	22	20	16	12
OFCL (2018-22)	22.1	34.0	45.4	56.0	70.9	78.7	100.5	117.8
OCD5 (2018-22)	36.7	73.4	114.0	156.9	193.2	244.5	317.0	376.0

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Pilar, 28 October – 5 November 2023. 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 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	26.1	42.3	55.4	78.2	111.8	151.2	251.7	326.2
OCD5	47.4	116.7	213.6	325.1	459.6	591.6	816.0	872.8
GFSI	37.3	63.2	79.9	105.5	147.8	204.5	320.5	430.3
EMXI	28.4	**39.8**	**45.7**	**54.7**	**67.7**	**85.1**	**144.2**	**228.2**
HMNI	30.2	51.9	63.0	**72.1**	**86.9**	**104.8**	**166.4**	**257.6**
HWFI	31.2	49.0	61.7	84.9	118.7	153.6	**232.7**	**316.6**
HFAI	36.5	55.4	71.1	97.5	140.8	198.1	345.0	436.2
HFBI	37.2	58.1	77.7	115.8	172.8	252.5	493.0	718.2
EGRI	**24.5**	**38.2**	**48.5**	**68.9**	**89.8**	**104.1**	**116.0**	**129.1**
CMCI	33.9	54.0	68.3	86.1	121.3	168.0	283.4	347.1
NVGI	30.7	57.3	87.8	122.7	154.2	166.0	**166.6**	**259.8**
CTCI	35.3	57.3	70.2	88.2	125.6	167.9	**250.5**	343.7
AEMI	35.4	62.6	81.4	106.1	148.9	201.2	296.5	377.4
HCCA	28.8	44.5	55.8	**76.4**	**105.5**	**148.9**	266.9	369.5
TVCE	29.5	45.9	**52.8**	**70.9**	**104.4**	**145.0**	**247.1**	347.9
TVCX	28.5	44.7	**52.0**	**67.9**	**99.5**	**138.2**	**237.8**	336.0
GFEX	31.8	49.0	56.3	**72.5**	**100.7**	**139.9**	**228.6**	327.4
TVDG	27.8	44.7	**51.1**	**67.5**	**99.6**	**139.1**	**232.7**	**325.6**
TABD	38.4	79.9	120.5	163.0	214.0	261.8	333.8	394.3
TABM	37.0	78.6	124.9	170.3	223.8	276.6	377.6	455.3
TABS	33.6	65.4	104.2	147.5	207.2	284.4	467.5	638.7
Forecasts	27	25	23	22	20	18	14	10

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Pilar, 28 October – 5 November 2023. 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	**3.8**	**5.4**	**6.9**	**7.3**	**5.5**	**3.8**	**6.2**	**7.1**
OCD5	5.9	13.3	20.0	24.4	15.0	13.9	14.3	14.5
Forecasts	30	28	26	24	22	20	16	12
OFCL (2018-22)	5.4	8.9	11.0	12.8	14.3	15.8	17.0	17.6
OCD5 (2018-22)	6.9	12.1	15.9	18.6	18.7	21.0	22.3	22.1

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Pilar, 28 October – 5 November 2023. 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 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	4.0	5.6	7.2	7.3	5.5	3.8	6.3	6.4
OCD5	6.1	13.5	20.2	24.4	15.0	13.9	15.1	13.9
HWFI	5.1	7.3	9.2	11.8	12.2	11.2	10.3	11.0
HMNI	4.8	6.2	**7.1**	9.8	11.6	12.7	15.3	14.0
HFAI	4.9	8.2	8.1	**6.6**	6.5	6.1	9.8	9.1
HFBI	5.9	8.6	**7.0**	**6.1**	6.3	8.4	9.0	9.5
CTCI	6.0	8.1	9.5	11.0	9.4	7.9	8.9	6.6
DSHP	5.0	6.2	7.4	8.5	9.9	7.8	12.5	17.0
LGEM	4.9	6.2	8.4	10.2	11.5	10.6	9.5	10.2
ICON	4.3	**5.5**	**6.6**	8.5	9.1	8.4	7.0	**5.9**
IVCN	4.4	6.3	**5.9**	**7.2**	7.4	7.2	6.7	**5.7**
IVDR	4.7	6.6	**5.9**	**7.2**	7.6	7.3	7.5	**6.0**
HCCA	5.0	6.3	9.2	7.5	6.9	7.3	16.1	14.4
GFSI	5.5	6.9	**6.8**	9.5	10.1	8.9	10.5	13.1
EMXI	**3.6**	**5.3**	**6.6**	7.3	7.2	7.6	12.3	10.0
Forecasts	29	27	25	24	22	20	15	11

Table 7. Coastal wind watch and warning summary for Tropical Storm Pilar, 28 October – 5 November 2023.

Date/Time (UTC)	Action	Location
29 / 2100	Tropical Storm Watch issued	Pacific coast of El Salvador
30 / 0300	Tropical Storm Watch issued	Puerto Sandino to Nicaragua/Honduras Border
30 / 0300	Tropical Storm Watch issued	Pacific coast of Honduras
1 / 1500	Tropical Storm Watch discontinued	Puerto Sandino to Nicaragua/Honduras Border
1 / 1500	Tropical Storm Watch discontinued	Pacific coast of Honduras
1 / 2100	Tropical Storm Watch discontinued	All

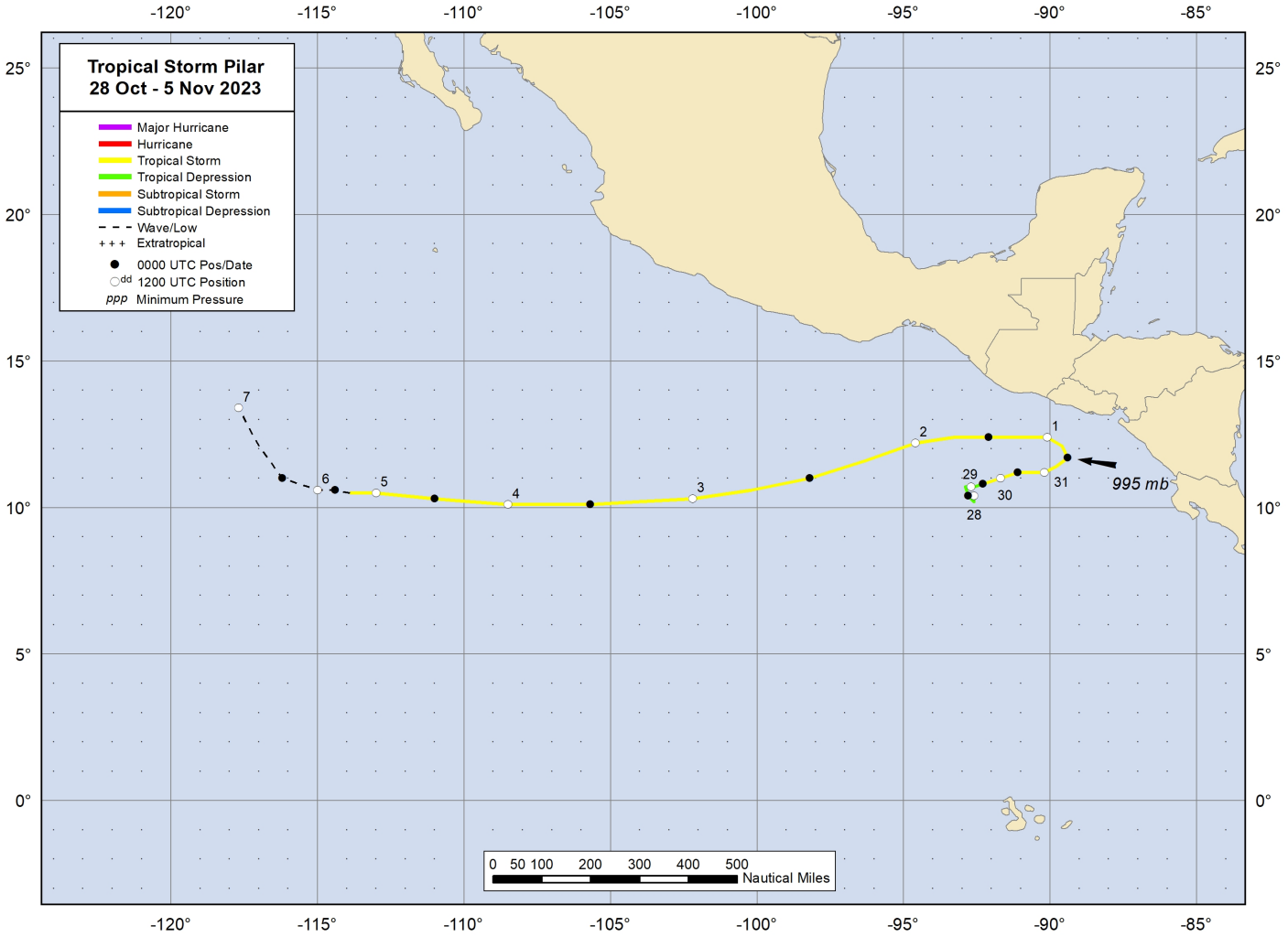


Figure 1. Best track positions for Tropical Storm Pilar, 28 October – 5 November 2023.

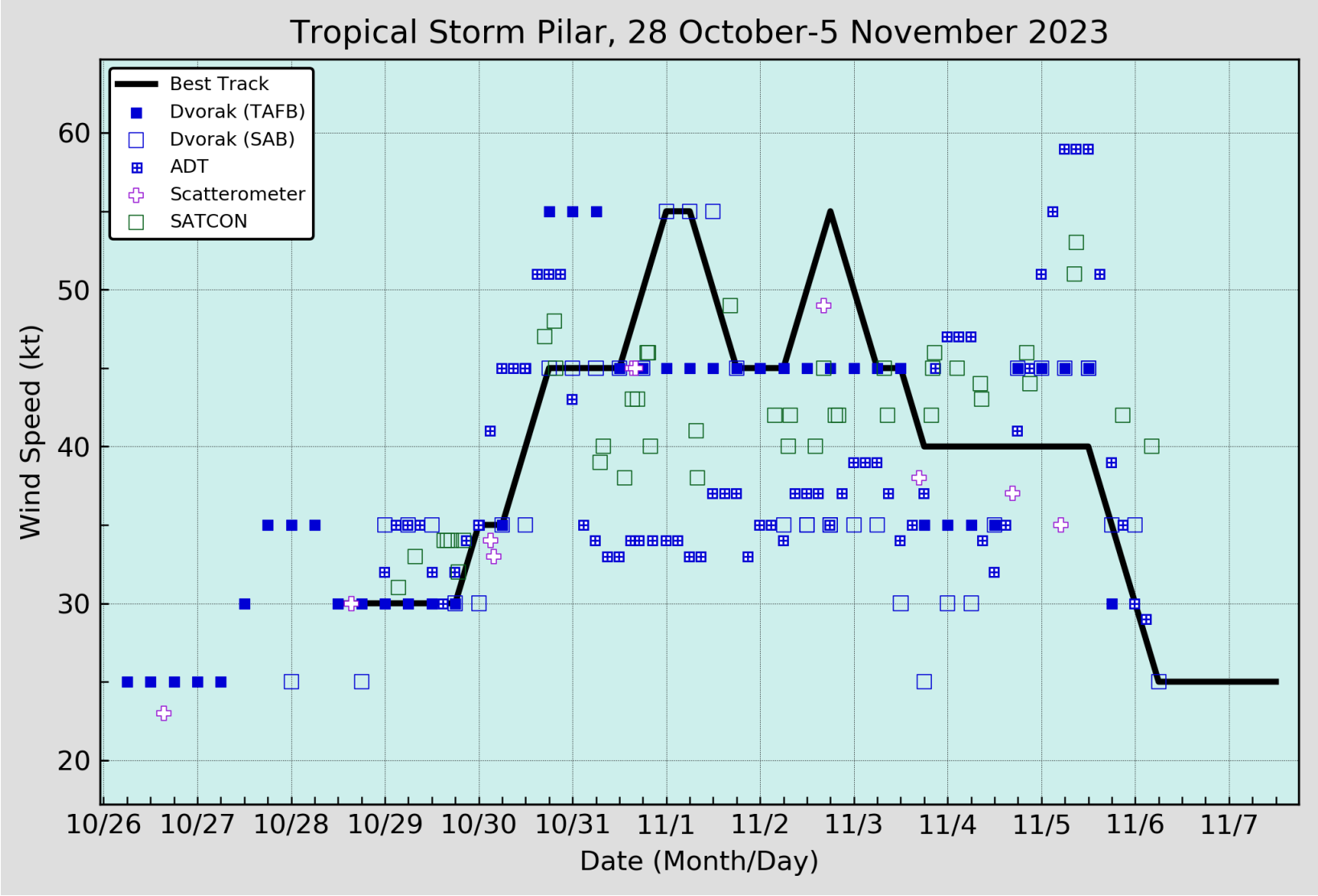


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Pilar, 28 October – 5 November 2023. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

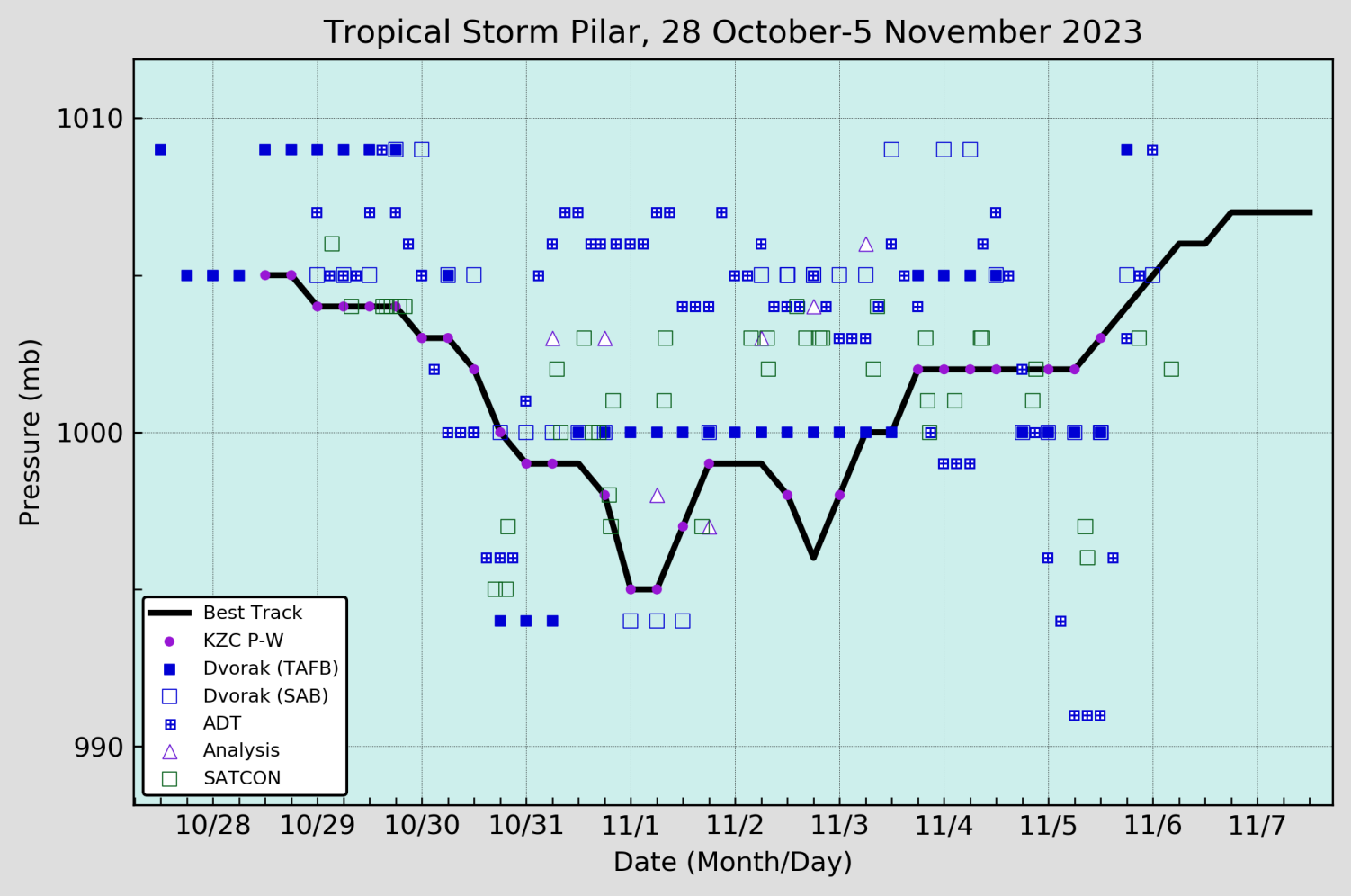


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Pilar, 28 October – 5 November 2023. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute 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.

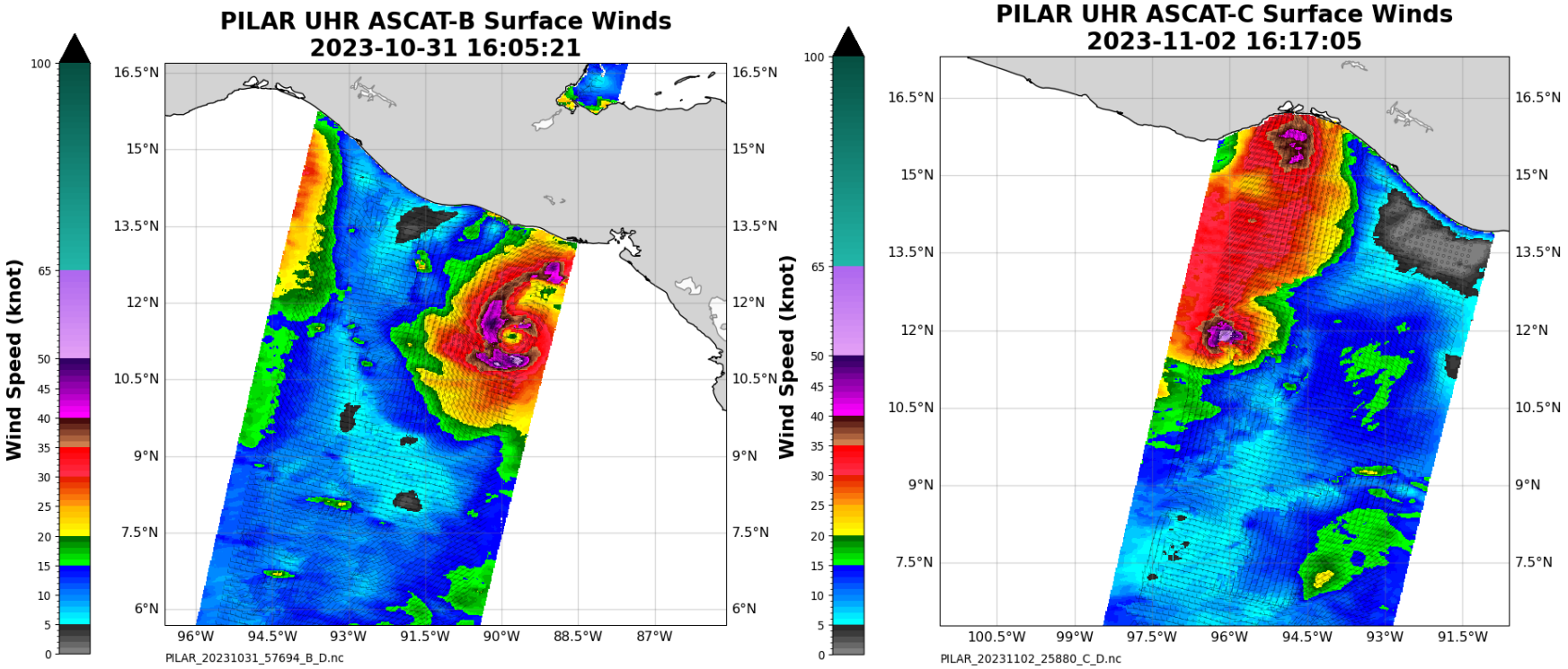


Figure 4. Ultra-high resolution scatterometer data during Pilar, both with maximum winds in the 50-55 kt range. Left panel is from 1605 UTC 31 October and the right panel is from 1617 UTC 2 November. Images courtesy NOAA NESDIS.

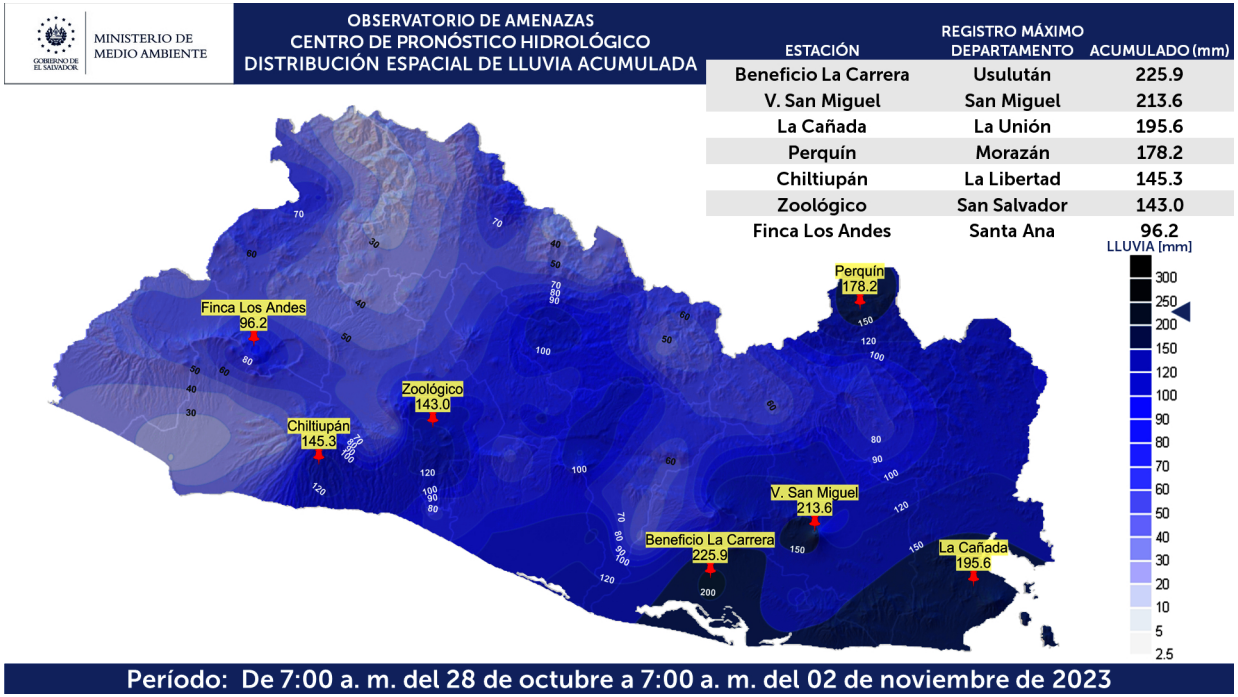


Figure 5. Rainfall (mm) from Pilar and its associated moisture over El Salvador from 28 October to 2 November 2023. Figure courtesy of the El Salvador Ministry of Environment.

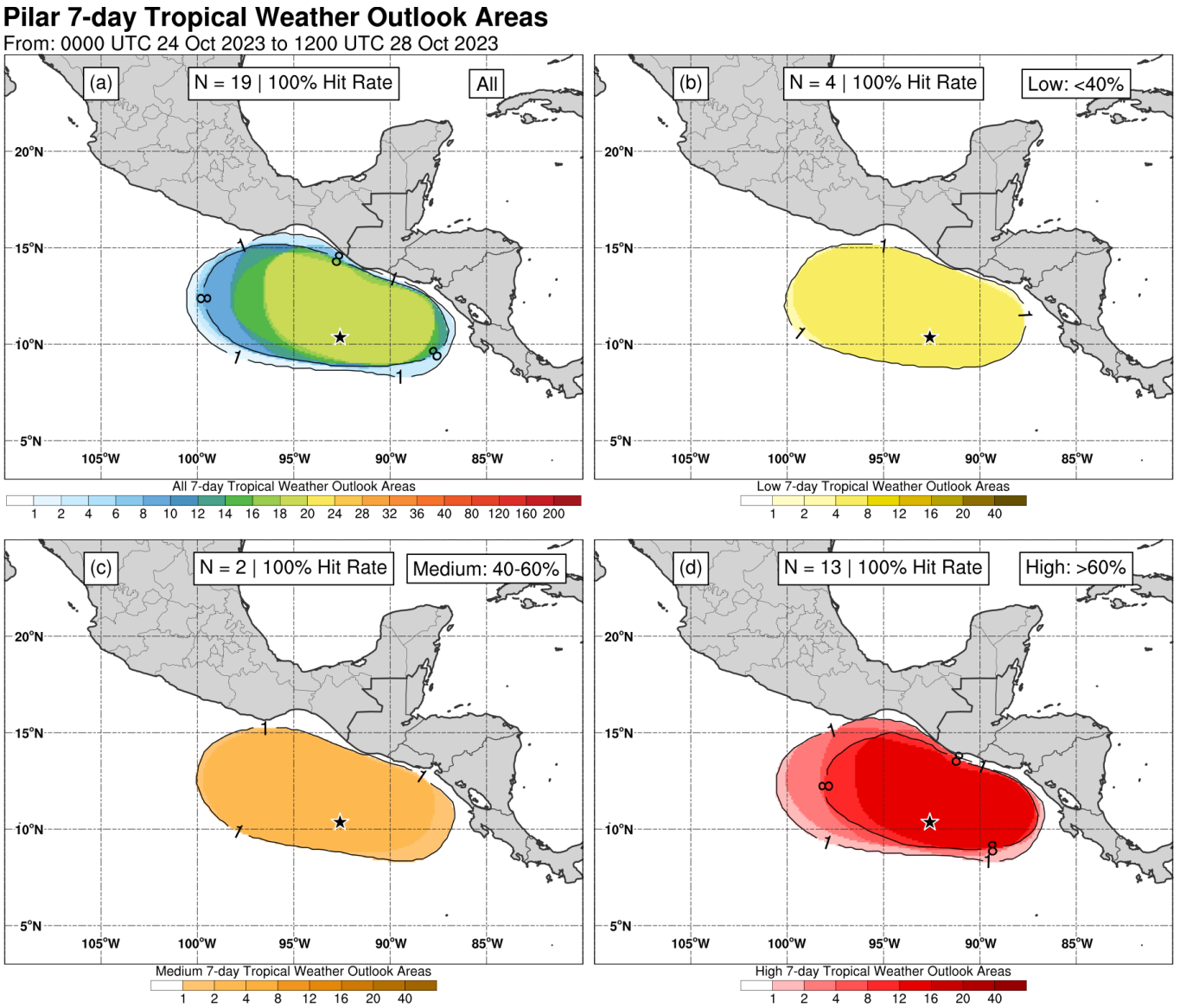


Figure 6. Composites of 7-day tropical cyclone genesis areas depicted in NHC's Tropical Weather Outlooks prior to the formation of Pilar for (a) all probabilistic genesis categories, (b) the low (<40%) category, (c) medium (40–60%) category, and (d) high (>60%) category. The location of genesis is indicated by the black star.