Tropical Cyclone Report
Hurricane Paula
(AL182010)
11 – 15 October 2010

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Paula was a small category 2 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that formed over the western Caribbean Sea and moved northward through the Yucatan Channel. It made landfalls as a tropical cyclone along the Honduras/Nicaragua border and in Cuba.

a. Synoptic History

Paula appears to have originated from a frontal boundary embedded within a broad low-level cyclonic gyre over the western and central Caribbean Sea, with possible contribution from a series of weak tropical waves. On 29 September, Tropical Storm Nicole moved northward out of the northwestern Caribbean Sea but left behind a broad low-level cyclonic circulation in the area. A cold front moved southeastward out of the Gulf of Mexico on 5 October and became a stationary trough axis the next day over the western Caribbean, oriented from north to south within the broad gyre. Deep convection increased along the trough axis when a tropical wave (that had previously contributed to the development of Hurricane Otto) reached the western Caribbean on 7 October. In the meantime, a second tropical wave moved across the Lesser Antilles on 6 October and reached the western Caribbean on 9 and 10 October. A broad low then formed after the second wave interacted with the trough, although deep convection waned late on 10 October. The convection began to redevelop early the next day, and it is estimated that a tropical depression formed by 0000 UTC 11 October while centered about 100 n mi southeast of Cabo Gracias a Dios at the coastal border between Nicaragua and Honduras. The depression then strengthened to a tropical storm 6 h later. The "best track" chart of Paula'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].

The center of Paula moved northwestward across the northeastern tip of Honduras (Cabo Gracias a Dios) near 1200 UTC 11 October and then reemerged over the northwestern Caribbean Sea as it was steered around the southwestern periphery of the subtropical ridge. The cyclone rapidly intensified over 29°C waters and reached hurricane intensity around 0000 UTC 12 October while centered about 85 n mi north-northwest of Puerto Lempira, Honduras. Paula continued to strengthen during the day, reaching its estimated peak intensity of 90 kt around 1800 UTC (Fig. 4), and it then moved toward the north-northwest and north as it came under the influence of a mid-latitude trough over the Gulf of Mexico. Paula was a small hurricane with

[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.

hurricane-force winds extending no more than 20 n mi from the center and tropical-storm-force winds no more than 60 n mi from the center. Indeed, the eye of Paula moved within 50 n mi of NOAA buoy 42056, and yet the highest wind reported by the buoy was 29 kt with a gust to 31 kt (Fig. 5).

Paula began to gradually weaken on 13 October while it headed northward toward the Yucatan Channel and an area of stronger shear over the Gulf of Mexico. The small hurricane stayed far enough offshore to prevent tropical-storm-force winds and heavy rainfall from reaching the Yucatan coast of Mexico, and Paula turned north-northeastward ahead of the mid-latitude trough early on 14 October (Fig. 6). Vertical shear increased during the day due to strong upper-level westerly winds, and Paula weakened to a tropical storm around 1200 UTC while heading northeastward toward the north coast of Cuba. Paula made landfall around 1500 UTC between Santa Lucía and Puerto Esperanza in the province of Pinar del Rio with maximum sustained winds near 55 kt.

Paula continued to weaken while it moved eastward across Cuba. The cyclone became a depression by 0600 UTC 15 October and then a remnant low 6 h later as it moved back offshore over the Atlantic Ocean near Sagua la Grande in the province of Villa Clara. The center of the low quickly became ill defined, and the cyclone dissipated just after 1800 UTC that day.

b. Meteorological Statistics

Observations in Paula (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) and objective Dvorak estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison (UW-CIMSS), as well as flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from seven flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM) and Aqua, the European Space Agency's Advanced Scatterometer (ASCAT), Defense Meteorological Satellite Program (DMSP) satellites, and the NRL WindSat, among others, were also useful in constructing the best track of Paula.

During the first Hurricane Hunter mission, a maximum 1500 ft flight-level wind of 77 kt (which supports a surface intensity of 62 kt) and a credible SFMR surface wind of 58 kt were reported at 1927 UTC 11 October. Paula was in the middle of a period of rapid intensification at the time, and based on interpolation between these data and earlier satellite classifications, it is estimated that the cyclone made landfall at Cabo Gracias a Dios along the Nicaragua/Honduras border with maximum sustained winds of 45 kt around 1200 UTC. However, the strongest winds were likely confined to areas of convection located off of the coast of Honduras and Nicaragua. These data also suggest that Paula became a hurricane by 0000 UTC 12 October, soon after the reconnaissance mission.

Paula's estimated peak intensity of 90 kt between 1800 UTC 12 October and 0000 UTC 13 October is based on an SFMR surface wind of 92 kt reported in light rain at 1700 UTC,

subjective satellite intensity estimates of 90 kt, and a maximum objective 3-h averaged ADT estimate of 90 kt. The maximum flight-level (700 mb) wind recorded was 96 kt at 0743 UTC 13 October. The 981 mb estimated minimum pressure is based on a measurement from a dropwindsonde at 1854 UTC 12 October.

The estimated intensity of 55 kt at landfall along the coast of Cuba on 14 October is based on an interpolation of the best track intensities at 1200 and 1800 UTC, which are supported by surface wind reports of 59 kt at 1407 UTC and 42 kt at 2102 UTC from two consecutive Hurricane Hunter missions.

Selected surface observations from land stations and data buoys are given in Table 2. The highest measured wind from a land station was 44 kt with a gust to 59 kt at La Palma, Cuba. The only ship that reported tropical-storm-force winds in association with Paula was the Royal Caribbean cruise ship *Radiance of the Seas* (call sign C6SE7), which reported 44-kt winds and a pressure of 1013 mb at 1300 UTC 12 October.

The only available rainfall measurement from Honduras was 3.31 in at Puerto Lempira, although it was reported by emergency officials that 150 to 200 mm (about 6 to 8 in) of rain fell in some regions. General amounts of 3 to 5 in were reported in the Cuban provinces of Pinar del Rio, La Habana, Ciudad La Habana, and Matanzas. The highest amount reported in Cuba was 7.32 in at Bahía Honda in Pinar del Rio.

c. Casualty and Damage Statistics

The head of Honduras' emergency agency reported that heavy rains and strong winds destroyed 19 homes in northeastern Honduras. In Cuba, the official newspaper *Granma* reported that the roofs of some homes and government buildings were damaged in western Pinar del Rio. In addition, some electrical pylons were toppled, and several banana plantations were damaged. In Havana, gas and power were knocked out or intentionally switched off as a precaution, and some streets were inundated with a foot or two of water.

Paula was directly responsible for one fatality. A 54-year-old man from Corpus Christi, Texas, drowned while swimming in rough surf off a beach in Cancun, Mexico.

d. Forecast and Warning Critique

The genesis of Paula was fairly well forecast. The area of disturbed weather from which Paula formed was first mentioned and given a "low" (0 to 20%) chance of genesis in the Tropical Weather Outlook (TWO) about 90 h before it became a tropical cyclone. The probability was increased to "medium" (30 to 50%) 36 h before genesis and "high" (greater than 50%) 30 h before genesis. However, forecaster confidence was still a little tentative, and the probabilities were lowered back to the "medium" category in the hours just before genesis is estimated to have occurred.

A verification of NHC official track forecasts for Paula is given in Table 3a. CLIPER errors were about average compared to the previous 5-yr means, but the official forecast track errors were lower than the mean official errors for that same period at forecast times between 12 and 48 h. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The official forecast was consistently beaten by the Florida State Superensemble (FSSE) and the variable corrected consensus (TVCC) at all forecast times between 12 and 72 h. The GFDL, GFDN, and the variable consensus TVCN also had some success, but otherwise none of the other track guidance had lower errors than the official forecast.

A verification of NHC official intensity forecasts for Paula is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period for the forecast times between 24 and 48 h. CLIPER5 errors were higher than those from the previous 5-yr period through 48 h, indicating that Paula's intensity was harder than usual to forecast. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. For the forecast periods between 12 and 48 h (for which there was a large enough sample), the official intensity forecasts were almost exclusively more skillful than the various intensity models. The only exceptions were the FSSE, which had lower errors at 12 h, and the HWRF (HWFI) and variable intensity consensus (IVCN), which had lower errors at 48 h.

Watches and warnings associated with Paula are given in Table 5. The governments of Honduras, Belize, Mexico, and Cuba issued tropical cyclone watches and warnings for portions of their respective coasts, although only Honduras and Cuba were affected by tropical-storm-force winds. Due to forecast uncertainties, a Tropical Storm Watch was issued for the Florida Keys from the Dry Tortugas to Craig Key even though the official forecast kept Paula farther south across Cuba. This was supported by the wind speed probability guidance at the time, which indicated a sizeable 35 to 40% chance of tropical-storm-force winds at point locations in the Lower and Middle Keys.

Acknowledgments:

El Instituto de Meteorología de la República de Cuba provided wind and pressure observations from Cuba, as well as estimates of the position, intensity, and pressure of Paula while it was over Cuba.

Table 1. Best track for Hurricane Paula, 11 – 15 October 2010.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
11 / 0000	13.9	81.8	1006	30	tropical depression
11 / 0600	14.4	82.5	1005	35	tropical storm
11 / 1200	15.0	83.2	1004	45	"
11 / 1800	15.7	83.8	1001	60	"
12 / 0000	16.5	84.4	996	65	hurricane
12 / 0600	17.3	85.0	991	65	"
12 / 1200	18.1	85.6	986	75	"
12 / 1800	18.8	85.9	981	90	"
13 / 0000	19.6	86.0	981	90	"
13 / 0600	20.3	86.0	984	85	"
13 / 1200	20.9	85.9	987	85	"
13 / 1800	21.4	85.8	990	75	"
14 / 0000	21.8	85.6	993	75	"
14 / 0600	22.2	85.2	995	70	"
14 / 1200	22.6	84.5	999	60	tropical storm
14 / 1500	22.7	83.9	1000	55	"
14 / 1800	22.8	83.5	1001	50	"
15 / 0000	22.9	82.0	1004	40	"
15 / 0600	22.9	80.9	1008	30	tropical depression
15 / 1200	22.9	79.9	1009	25	low
15 / 1800	23.0	79.1	1009	20	"
16 / 0000					dissipated
12 / 1800	18.8	85.9	981	90	maximum wind and minimum pressure
11 / 1200	15.0	83.2	1004	45	landfall near Cabo Gracias a Dios, Honduras/Nicaragua border
14 / 1500	22.7	83.9	1000	55	landfall between Santa Lucía and Puerto Esperanza, Cuba

Table 2. Selected surface observations for Hurricane Paula, 11 – 15 October 2010.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Honduras								
Puerto Lempira (MHPL)	11/1800	1006.0	11/1800	30				3.31
Cuba								
Pinar del Rio								
Cabo de San Antonio (78310)	14/0800	1008.9	14/0624	42	52			4.40
Santa Lucía (78312)	14/1450	1000.1	14/1604	43	54			
Isabel Rubio (78313)	14/0901	1010.4	14/1340	21	28			
Pinar del Río (78315)	14/1700	1008.7	14/1702	25	35			
La Palma (78316)	14/1740	1001.5	14/1758	44	59			
Paso Real de San Diego (78317)	14/1800	1006.3	14/1400	35	46			
Bahía Honda (78318)	14/1850	1008.0	14/1914	43	57			4.29
Bahía Honda								7.32
CAI (Sugar Agroindustrial Complex) Pablo de la Torriente Brau								5.04
Luis Carrasco								4.88
CAI Harlem								4.41
Sabanilla								4.33
Ciro Redondo								4.06
Ciudad de La Habana								
Casa Blanca (78325)			14/2240	40	55			
Santiago de las Vegas (78373)	14/2155	1001.8	14/2255	33	44			
Perla								5.08
Virgen del Camino								4.84
La Palma								3.94
La Habana								
Güira de Melena (78320)	14/2000	1005.1	14/2235	39	52			
Melena del Sur (78375)	14/2200	1000.3	14/2220	38	52			
Batabanó (78322)	14/2200	1004.0	14/2300	42	57			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Güines (78323)	15/0000	1004.3	14/2145	35	46			
Bainoa (78340)	15/0005	1005.0	15/0053	25	34			
Mariel								4.65
Presa Maurin								3.94
Matanzas								
Unión de Reyes (78327)	15/0100	1008.0						
Varadero (78328)	15/0100	1009.4						
Indio Hatuey (78329)	15/0500	1007.2						
Jovellanos (78330)	15/0145	1009.8						
Jagüey Grande (78331)	15/0100	1007.8						
Colón (78332)	15/0530	1008.5						
Playa Girón (78333)	15/0100	1010.9						
Cárdenas								4.25
Limonar								4.09
Camarioca								4.02
Buoys								
Yucatan Basin (42056)	12/2350	1008.6	13/0000	29	31			

[a] Date/time is for the sustained wind in Honduras and from buoys, and for the gusts in Cuba.
[b] Except as noted, sustained wind averaging periods for land-based ASOS reports are 2 min; wind averaging periods for Cuban observations and buoys are 1 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Paula, 11 – 15 October 2010. Mean errors for the 5-yr period 2005-9 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	**21.8**	**33.7**	**49.7**	**72.1**	198.5		
OCD5	39.1	94.8	154.5	212.7	314.1		
Forecasts	14	12	10	8	4		
OFCL (2005-9)	31.8	53.4	75.4	96.8	143.8	195.6	252.1
OCD5 (2005-9)	46.9	97.3	155.4	211.6	304.8	387.9	467.8

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Paula, 11 – 15 October 2010. 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	17.2	27.9	41.1	82.1	242.8		
OCD5	39.6	94.3	161.2	250.7	419.9		
GFSI	18.0	35.7	44.7	90.0	248.1		
GHMI	**13.6**	35.1	54.4	**63.8**	**78.0**		
HWFI	20.9	43.2	70.2	116.5	**228.8**		
GFNI	29.0	65.1	77.8	**78.3**	**116.6**		
NGPI	37.4	74.4	107.0	150.5	243.6		
EMXI	22.8	52.7	68.5	127.0	323.4		
NAMI	47.2	109.5	196.8	293.9	497.3		
AEMI	21.7	59.6	94.8	124.7	**145.9**		
FSSE	**11.6**	**24.9**	**36.8**	**61.3**	**133.4**		
TVCN	**15.2**	32.3	43.2	**79.5**	**173.9**		
TVCC	**11.1**	**27.5**	**39.3**	**70.9**	**170.2**		
LBAR	34.0	118.2	220.8	377.3	663.8		
BAMD	51.7	132.3	212.3	311.2	411.1		
BAMM	28.8	67.1	89.0	120.4	354.5		
BAMS	35.1	87.8	135.2	219.2	588.4		
Forecasts	8	7	6	4	1	0	0

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Paula, 11 – 15 October 2010. Mean errors for the 5-yr period 2005-9 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	8.2	**10.0**	**10.5**	**11.9**	18.8		
OCD5	13.3	21.3	27.8	29.8	8.8		
Forecasts	14	12	10	8	4		
OFCL (2005-9)	7.0	10.7	13.1	15.2	18.6	18.7	20.1
OCD5 (2005-9)	8.6	12.5	15.8	18.2	21.0	22.7	21.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Paula, 11 – 15 October 2010. 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	7.5	7.5	7.5	11.7	25.0		
OCD5	11.4	19.0	26.8	32.7	**6.0**		
GHMI	10.6	13.1	13.6	11.7	27.0		
HWFI	10.6	11.7	12.4	**11.5**	**16.0**		
GFNI	11.7	15.5	14.3	12.0	**4.5**		
FSSE	**7.3**	8.5	9.9	11.7	32.5		
DSHP	7.9	10.9	10.6	14.7	35.0		
LGEM	9.0	13.6	15.4	18.3	37.5		
ICON	8.6	11.4	12.0	12.2	29.0		
IVCN	9.2	12.1	11.8	**11.2**	**24.5**		
Forecasts	12	10	8	6	2	0	0

Table 5. Watch and warning summary for Hurricane Paula, 11 – 15 October 2010.

Date/Time (UTC)	Action	Location
11 / 2100	Tropical Storm Warning issued	Limon, Honduras to Honduras/Nicaragua border including Bay Islands
11 / 2100	Tropical Storm Warning issued	Chetumal to Punta Gruesa, Mexico
11 / 2100	Hurricane Warning issued	Punta Gruesa to Cancun, Mexico including Cozumel
12 / 0000	Tropical Storm Watch issued	Belize
12 / 0300	Tropical Storm Warning issued	Cabo Catoche to San Felipe, Mexico
12 / 0300	Hurricane Warning modified to	Punta Gruesa to Cabo Catoche including Cozumel
12 / 0900	Tropical Storm Watch discontinued	Belize
12 / 1200	Tropical Storm Warning discontinued	Limon to Honduras/Nicaragua border including Bay Islands
12 / 2100	Tropical Storm Warning discontinued	Chetumal to Punta Gruesa
12 / 2100	Hurricane Warning issued	Pinar del Rio, Cuba
13 / 0300	Hurricane Warning discontinued	Punta Gruesa to Punta Allen, Mexico
13 / 1500	Tropical Storm Watch issued	Dry Tortugas to Craig Key, Florida
13 / 1500	Tropical Storm Warning modified to	Cancun to San Felipe
13 / 1500	Hurricane Warning discontinued	Punta Allen to Cabo Catoche
13 / 2100	Tropical Storm Warning discontinued	Cancun to San Felipe
13 / 2100	Tropical Storm Warning issued	La Habana and Ciudad de la Habana, Cuba
14 / 1200	Hurricane Warning changed to Tropical Storm Warning	Pinar del Rio
15 / 0000	Tropical Storm Watch discontinued	All
15 / 0300	Tropical Storm Warning discontinued	All

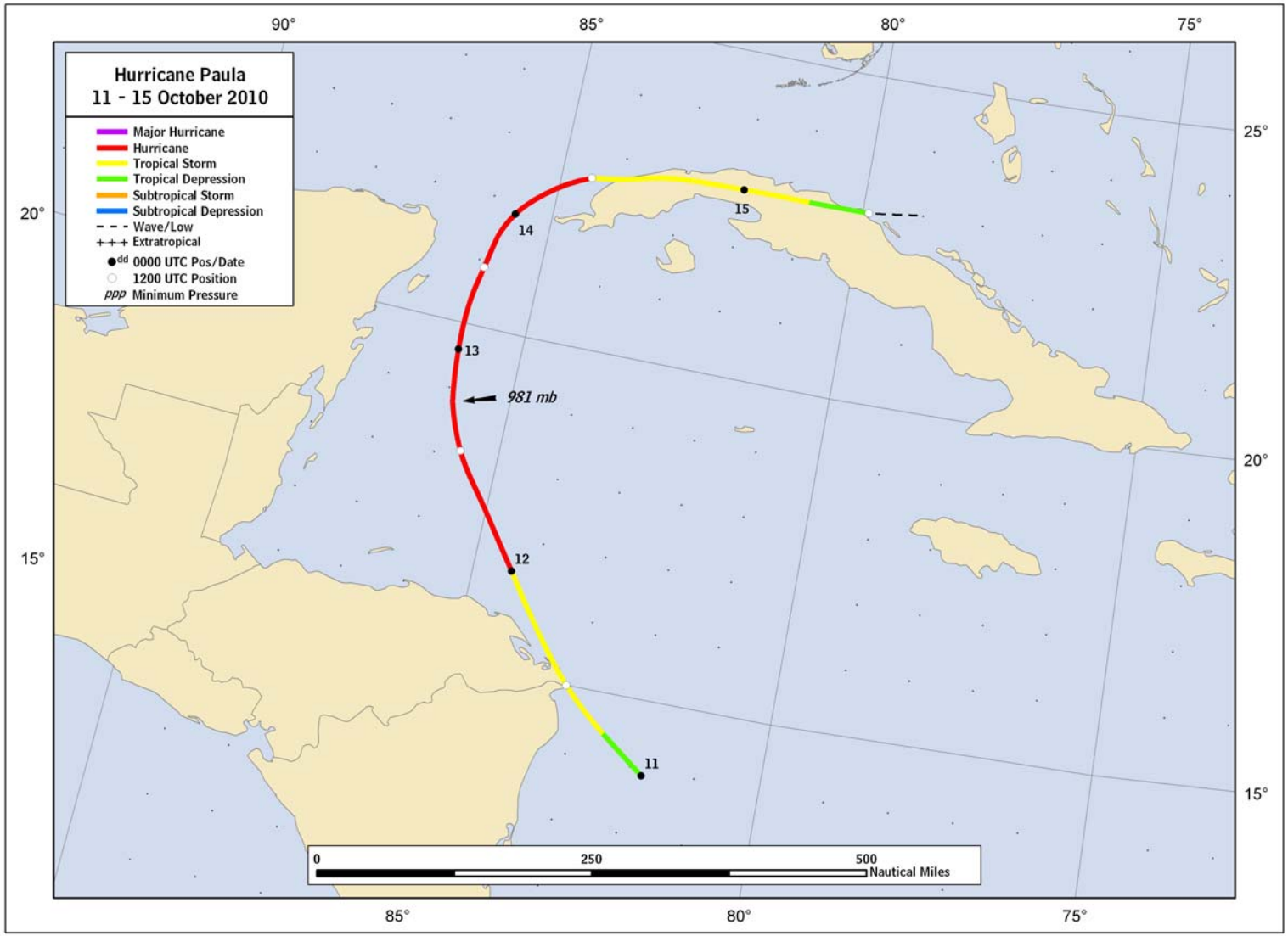

Figure 1. Best track positions for Hurricane Paula, 11 – 15 October 2010.

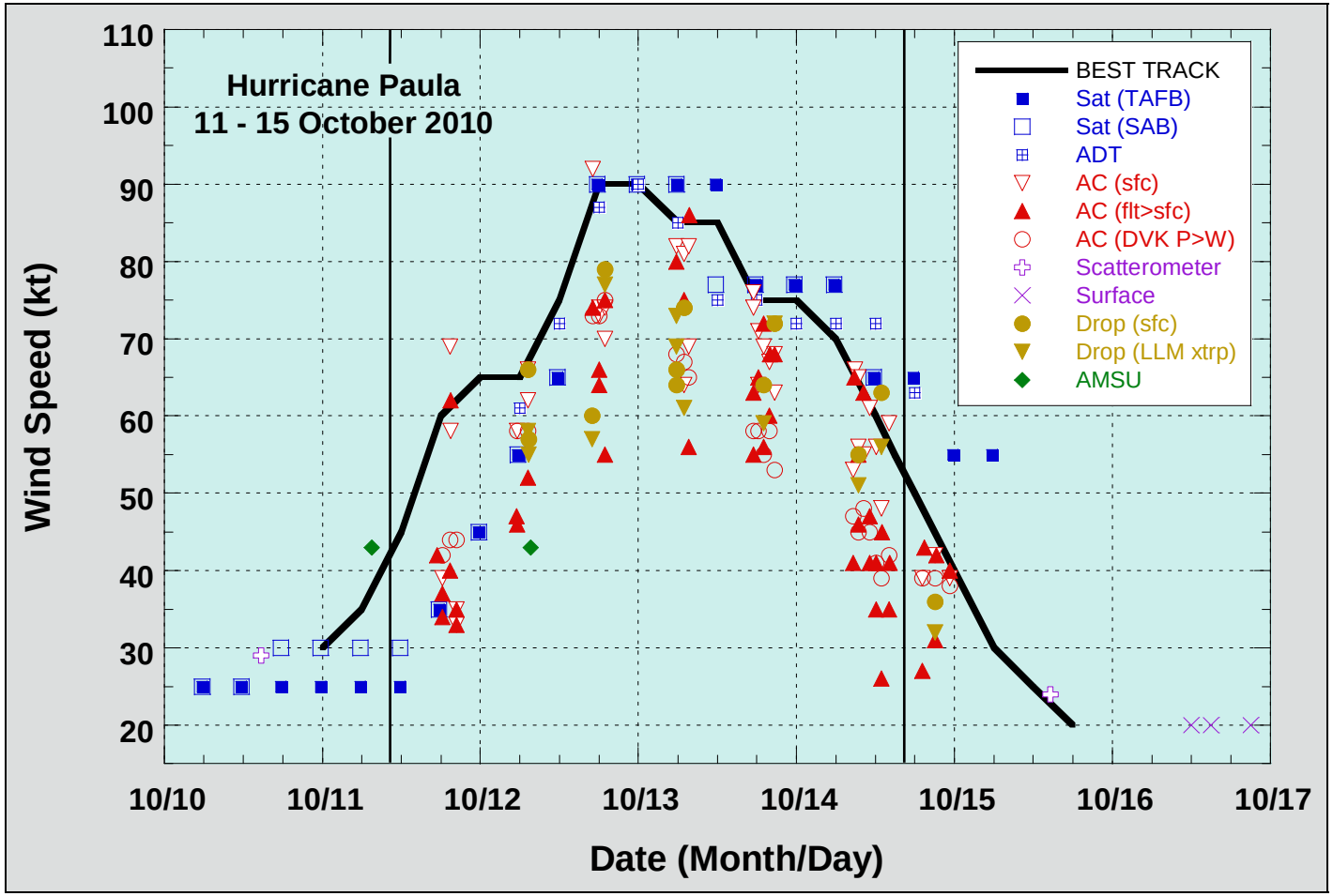

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Paula, 11 – 15 October 2010. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. AMSU intensity estimates are from the UW-CIMSS technique. Solid vertical lines correspond to landfalls.

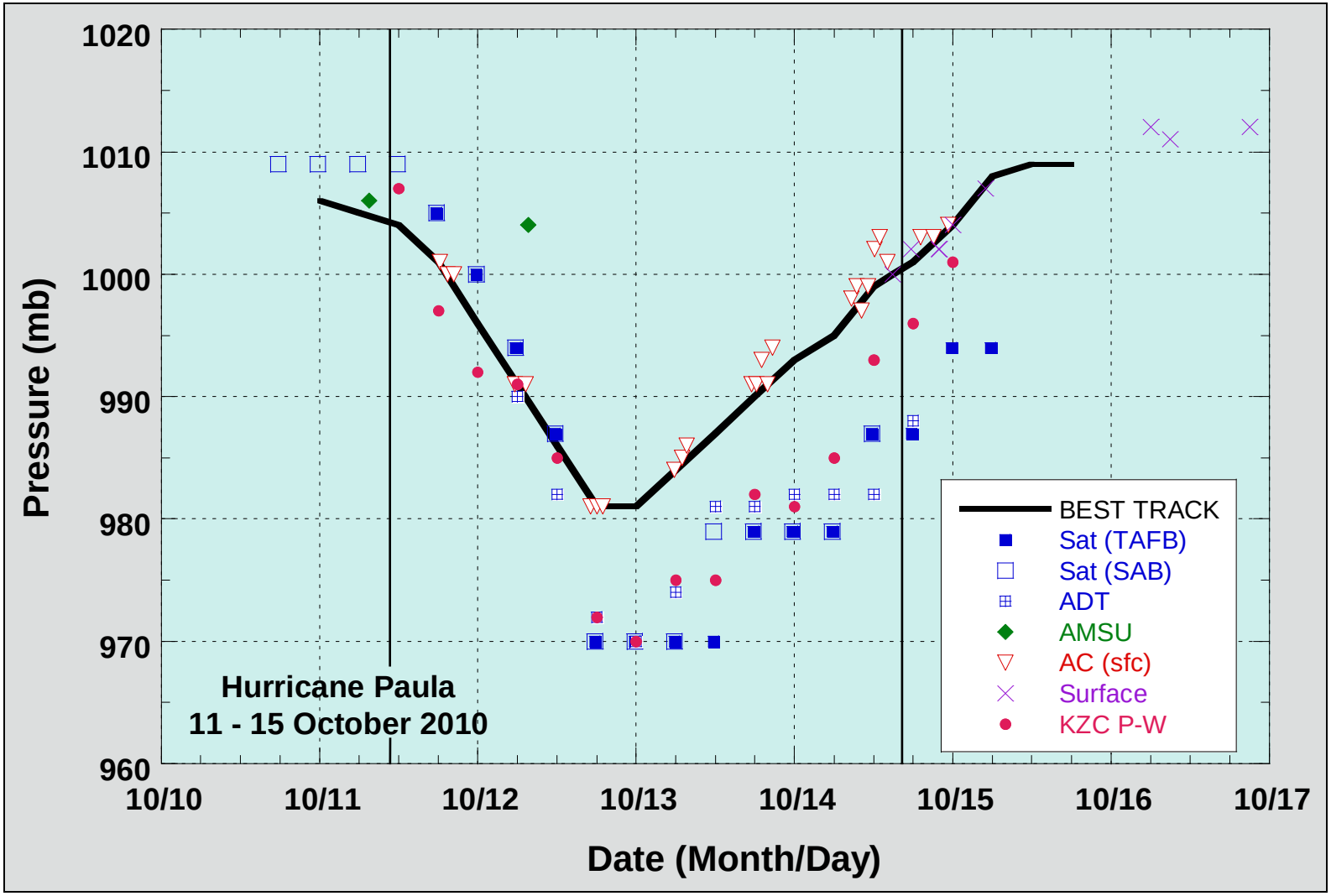

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Paula, 11 – 15 October 2010. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC. AMSU intensity estimates are from the UW-CIMSS technique. Solid vertical lines correspond to landfalls.

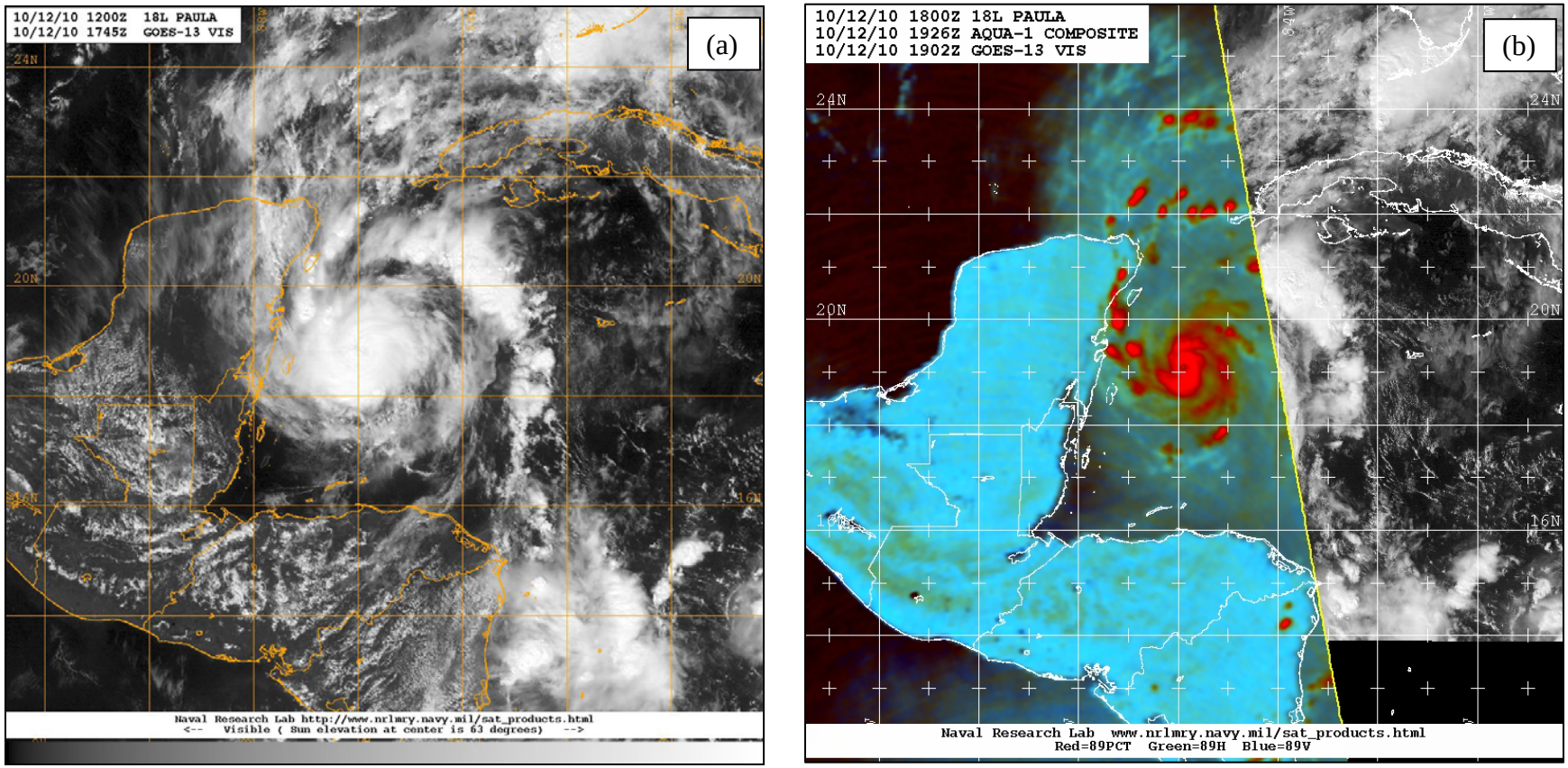

Figure 4. (a) GOES-13 visible image at 1745 UTC 12 October 2010 and (b) 89 GHz color composite AMSR-E image at 1926 UTC 12 October 2010 of Hurricane Paula near the time it reached its estimated peak intensity of 90 kt. Images courtesy of the Naval Research Laboratory in Monterey, CA.

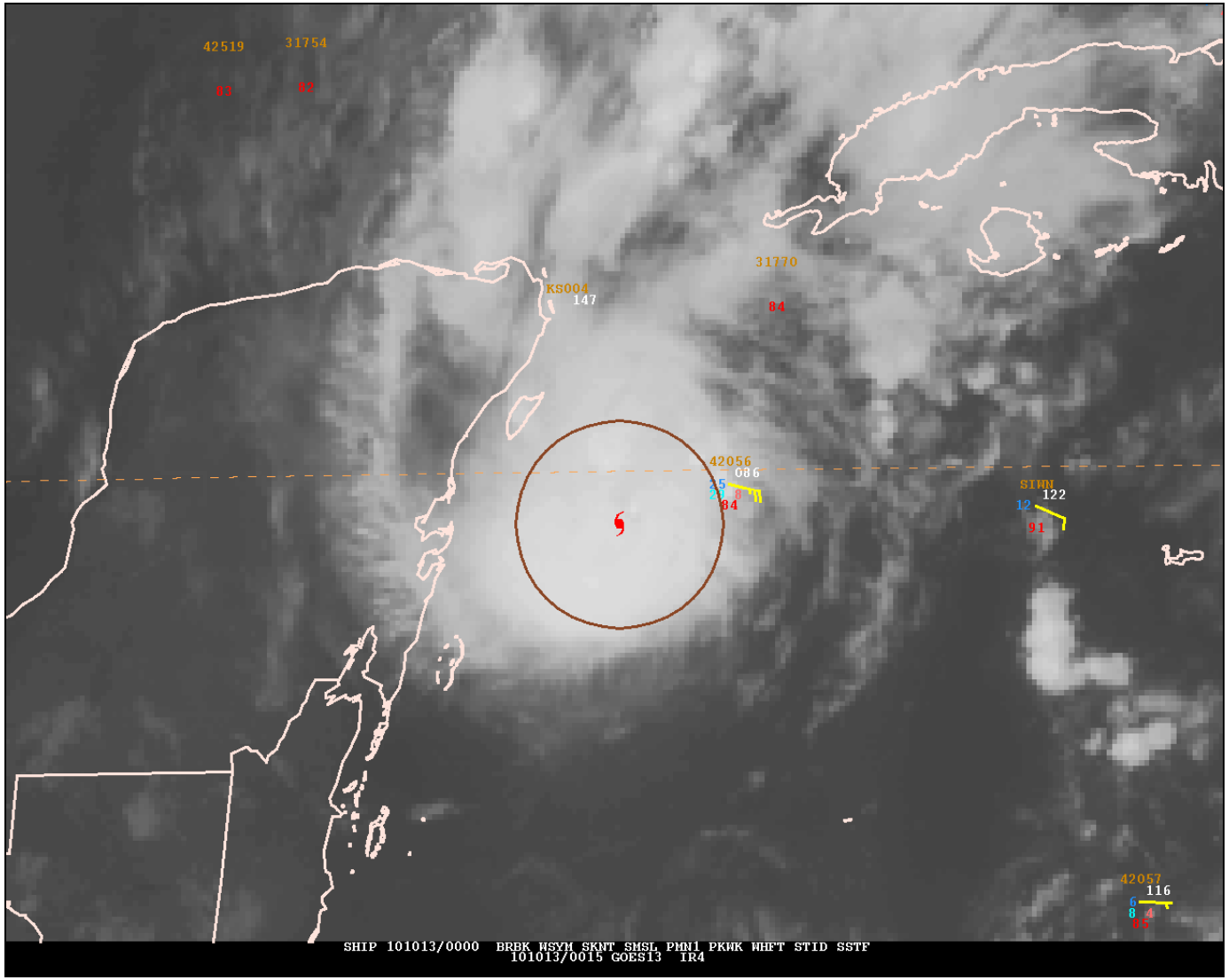

Figure 5. GOES-13 infrared image at 0015 UTC 13 October 2010 near the time that NOAA buoy 42056 registered its highest 1-minute sustained wind during Paula's passage. The center of the hurricane is denoted by the small red hurricane symbol, and the approximate tropical-storm-force wind field (radius of 50 n mi) is depicted by the brown circle.

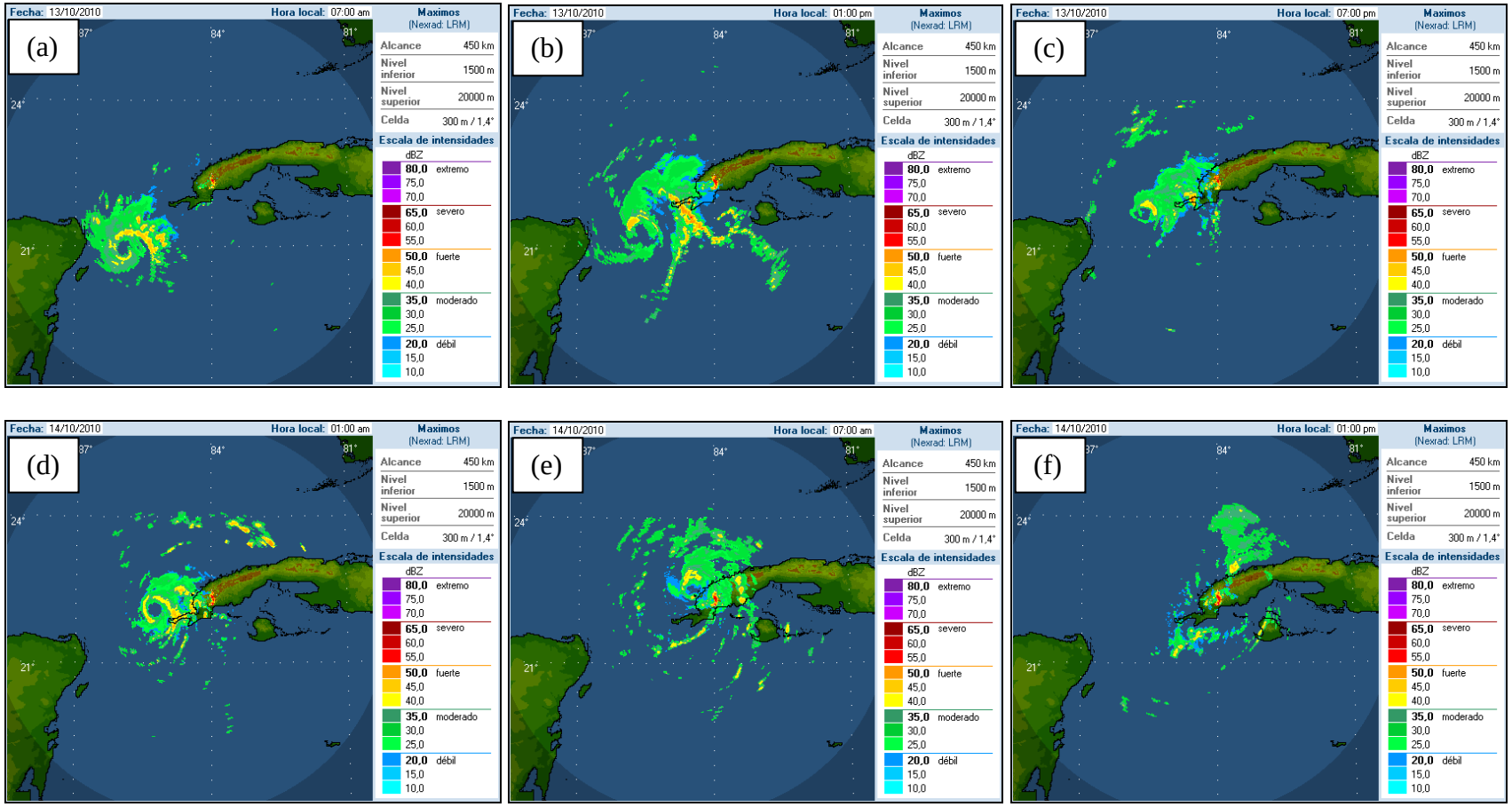

Figure 6. Series of six-hourly radar images from Bajada, Cuba, at (a) 1200 and (b) 1800 UTC 13 October 2010 and (c) 0000, (d) 0600, (e) 1200, and (f) 1800 UTC 14 October 2010, depicting the evolution of Hurricane Paula as it approached and made landfall in Cuba (as a tropical storm). Radar imagery courtesy of el Instituto de Meteorología de la República de Cuba.