NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE BARBARA

(EP022013)

28 – 30 May 2013

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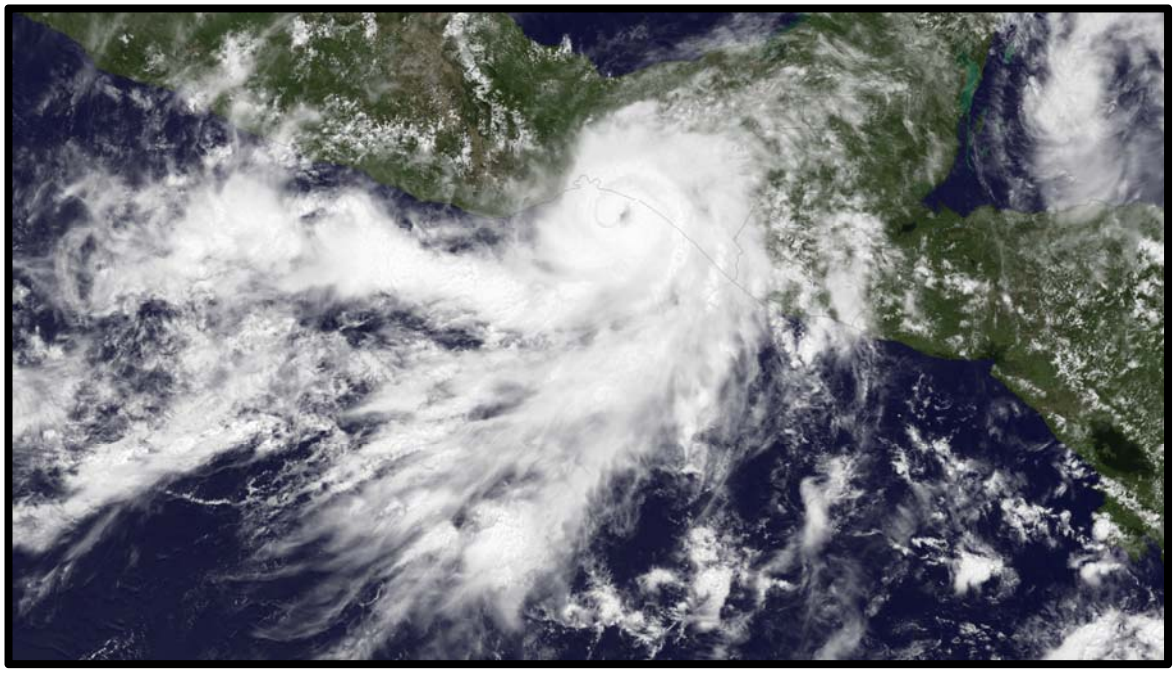

GOES 14 SATELLITE IMAGE OF HURRICANE BARBARA AT 1815 UTC 29 MAY, NEAR THE TIME OF LANDFALL IN SOUTHERN MEXICO. IMAGE COURTESY OF THE NOAA ENVIRONMENTAL VISUALIZATION LABORATORY.

Barbara was an early season category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that made landfall along the Pacific coast of southeastern Mexico. Barbara's landfall location is the easternmost recorded landfall point for an eastern North Pacific hurricane. Barbara's landfall date of 29 May marks the second-earliest hurricane landfall date in the basin since records began in 1949.

[1] Original report date 6 August 2013. Corrected for tropical cyclone status in Table 1 and Figure 1.

Hurricane Barbara

28 – 30 MAY 2013

SYNOPTIC HISTORY

Barbara appears to have formed from the interaction of a tropical wave with an eastward-moving atmospheric Kelvin wave during an active period of the Madden-Julian Oscillation (Fig.1). Satellite data suggest that the low-amplitude tropical wave departed the west coast of Africa on 16 May and crossed Central America on 24 May. The wave moved over the far eastern Pacific Ocean shortly thereafter, and a broad low pressure area formed southwest of the coast of Nicaragua on 25 May after the atmospheric Kelvin wave passed the longitude of the disturbance (Fig. 1). The broad low moved west-northwestward during the next few days while the associated shower and thunderstorm activity gradually increased. Early on 28 May, the circulation became better defined, which resulted in the formation of a tropical depression by 1200 UTC, about 110 n mi south-southeast of Puerto Angel, Mexico. The "best track" chart of the tropical cyclone's path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[2].

While moving slowly northward in a low wind shear environment and over waters near 30°C, the depression quickly strengthened and became a tropical storm 6 h after genesis. Around that time, a period of rapid intensification began as Barbara turned northeastward toward the coast of southern Mexico. Microwave satellite imagery from early on 29 May indicated that the structure of Barbara improved, with the development of an inner core (Fig. 5) and a low-level eye feature. A few hours later radar data from Puerto Angel also indicated that the inner core had become better defined and by 1200 UTC Barbara had estimated maximum winds of 55 kt. During the daylight hours of 29 May, Barbara continued to intensify while it accelerated northeastward ahead of a deepening mid-latitude trough that extended southward from the south-central United States. Barbara attained hurricane strength by 1800 UTC when the eye became apparent in visible satellite images. Less than 2 h later, around 1950 UTC, the hurricane made landfall near the border between the Mexican states of Oaxaca and Chiapas, about 15 n mi west-southwest of Tonalá, with an estimated intensity of 70 kt.

The category 1 hurricane quickly weakened while moving northward across the Sierra Madre Mountains. Barbara's peak winds are estimated to have weakened to 50 kt by 0000 UTC 30 May, and it weakened to tropical depression 6 h later. By the time the low-level center of Barbara emerged into the Bay of Campeche, shortly after 1200 UTC 30 May, the cyclone had lost its deep convection and degenerated into a remnant low. The low continued to weaken

[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.

over the Bay of Campeche and the system became a trough of low pressure over the extreme southern Gulf of Mexico by 0000 UTC 31 May.

METEOROLOGICAL STATISTICS

Observations in Barbara (Figs. 3 and 4) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), and objective Advanced Dvorak Technique (ADT) 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 Tropical Rainfall Measuring Mission (TRMM), 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 Barbara.

Barbara's estimated peak and landfall intensity of 70 kt is based on a blend of subjective Dvorak intensity estimates of 65 and 77 kt from TAFB and SAB, respectively. The 70-kt intensity is also supported by a microwave-adjusted ADT estimate of 72 kt and a post-landfall AMSU intensity estimate of 69 kt. Operationally, the ADT did not switch to an eye scene type prior to landfall and estimated Barbara's intensity at 53 kt. However, a post-storm adjusted CI number that used microwave data to detected the eye, yielded intensity estimates of 67 kt at 1745 UTC and 72 kt at landfall.

Radar data from Puerto Angel, Mexico, were useful in assessing inner core structure changes and the development of the eye on 29 May. Navigation issues, however, did not allow the use of the radar data for position estimates or determining a precise landfall location or time.

Selected surface observations from land stations are given in Table 2. A sustained wind of 36 kt with a gust to 65 kt was reported at 2045 UTC 29 May at an automated observing site at Paredón, Mexico. A wind gust of 56 kt was recorded at Arriaga, Mexico, around 2100 UTC. The automated observing station at Arriaga, located at 15 n mi north-northeast of the landfall location at an elevation of 62 m, also measured a minimum station pressure of 981.9 mb at 2100 UTC 29 May. Adjusting the station pressure to sea level results in an estimated pressure of 988.6 mb. Since this station was reporting 32 kt winds at the time of the lowest pressure reading, the minimum pressure of the hurricane was likely a few millibars lower. Incorporating the 2100 UTC pressure observation from Arriaga, Barbara's estimated minimum pressure at landfall is 983 mb.

A rainfall analysis provided by the Mexican Weather Service indicates that rainfall amounts of 4-8 inches were common across the Mexican state of Chiapas. Isolated maximum amounts of 12-16 inches were reported. The observing site at Arriaga, Mexico, received 16.83 inches during the 24-h period ending at 1200 UTC 30 May.

Barbara nearly became a rare Pacific to Atlantic basin-crossing tropical cyclone. Had this occurred Barbara would have been the first tropical cyclone to retain its name during a Pacific-Atlantic basin crossing since new naming rules went into effect in 2001. However, by

the time the center of Barbara emerged into the extreme southern Gulf of Mexico the cyclone had lost its deep convection and degenerated into a remnant low.

There were no ship reports of winds of tropical storm force or greater in association with Barbara.

CASUALTY AND DAMAGE STATISTICS

Reports from the media and civil defense authorities indicate that Barbara was responsible for three direct deaths[3] in Mexico. A United States citizen drowned while surfing near the town of Puerto Escondido in the Mexican state of Oaxaca. The location of this death was well west of the landfall location, but it occurred in rough surf conditions directly associated with Barbara. Two additional deaths occurred in flooding associated with Barbara in the Mexican state of Oaxaca. A 27-year-old man drowned crossing a swollen creek, and a 61-year-old man drowned in a river in Santa Cruz Zenzontepec. Fourteen fishermen were reported missing during the storm, but subsequent media reports seem to indicate that all were accounted for in the days following Barbara's landfall. Several of the fishermen took refuge on the island of El Caballar.

Rains from Barbara caused widespread flooding in southern Mexico. Although specific damage reports and dollar amounts are not available, rain and wind from Barbara affected 3500 hectares of mango production in the region, with losses estimated at 10-15 million pesos, or $750,000 to $1.1 million USD.

FORECAST AND WARNING CRITIQUE

The development of Barbara was well forecast. The disturbance from which Barbara formed was introduced in the Tropical Weather Outlook at 0000 UTC 25 May, about 84 h before genesis occurred. Initially, the disturbance was assessed to have a low chance (<30%) of development during the next 48 h. The chance of development was raised to the medium category (30 to 50%) at 1800 UTC 26 May, 42 h before genesis, and to the high category (>50%) at 1200 UTC 27 May, 24 h before formation occurred.

A verification of NHC official track forecasts for Barbara is given in Table 3a and a homogenous comparison of the official track errors with selected guidance models is given in Table 3b. Due to the small number of forecasts, a meaningful comparison of the official forecast with the various track models is not possible. That said, the NHC track errors were higher than

[3] 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.

the mean official errors for the previous 5-yr period at 24 and 36 h. The NHC forecasts exhibited a westward bias (Fig. 6), with the first few official track forecasts indicating landfall over the western portion of the Gulf of Tehuantepec. The actual landfall location occurred along the eastern portion of the coast of the Gulf of Tehuantepec.

A verification of NHC official intensity forecasts for Barbara is given in Table 4a and a homogenous comparison of the official intensity errors with selected guidance models is given in Table 4b. The NHC intensity forecasts and much of the intensity guidance did not predict the rapid strengthening of Barbara before landfall. The first few NHC forecasts, however, were at or higher than most of the intensity guidance. This resulted in the NHC forecasts having smaller mean intensity errors than all of the intensity guidance at 12 and 24 h.

Watches and warnings issued by the government of Mexico in association with Barbara are given in Table 5. The possible need for a tropical storm watch or warning was first discussed in the NHC Tropical Weather Outlook issued at 1200 UTC 27 May, 24 h before formation, and about 56 h before Barbara crossed the coast of southern Mexico as a hurricane. A tropical storm warning was issued by the government of Mexico with the first NHC advisory at 2100 UTC 28 May, and a hurricane watch was issued 12 h later at 0900 UTC 29 May. The government of Mexico issued a hurricane warning at 1025 UTC 29 May.

Table 1. Best track for Hurricane Barbara, 28-30 May 2013.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 1200	13.9	96.1	1006	30	tropical depression
28 / 1800	14.1	96.1	1004	35	tropical storm
29 / 0000	14.2	96.0	1001	40	"
29 / 0600	14.6	95.5	998	50	"
29 / 1200	15.1	94.8	994	55	"
29 / 1800	15.7	94.2	986	65	hurricane
29 / 1950	16.0	94.0	983	70	"
30 / 0000	16.7	93.9	993	50	tropical storm
30 / 0600	17.6	93.9	1001	30	tropical depression
30 / 1200	18.2	93.9	1004	25	low
30 / 1800	18.8	93.9	1006	20	"
31 / 0000					dissipated
29 / 1950	16.0	94.0	983	70	Maximum winds, minimum pressure, and landfall about 15 n mi west-southwest of Tonalá, Mexico

Table 2. Selected surface observations from land stations in Mexico in association with Hurricane Barbara, 28-30 May 2013.

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)	
Arriaga, Chiapas (16.24°N 93.91°W)	29/2100	988.6[b]	29/2100	32	56	16.83[c]
Tonalá, Chiapas (16.08°N 93.74°W)			29/1940		38	
Paredón, Chiapas (16.06°N 93.86°W)	29/2015	995.3	29/2045	36	65	

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Converted from a minimum station pressure of 981.9 mb.
[c] 24 h rainfall total ending at 1200 UTC 30 May.

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Barbara, 28-30 May 2013. 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	72	96	120
OFCL	**26.7**	66.8	91.5				
OCD5	56.3	161.8	306.2				
Forecasts	5	3	1				
OFCL (2008-12)	27.0	43.1	57.8	71.9	101.7	137.2	165.9
OCD5 (2008-12)	37.4	73.0	114.9	158.3	238.4	313.5	389.1

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Barbara, 28-30 May 2013. 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	26.7	66.8	91.5				
OCD5	56.3	161.8	306.2				
GFSI	**22.3**	**61.1**	**76.6**				
GHMI	**25.5**	**55.9**	96.2				
HWFI	34.5	84.3	160.1				
EMXI	32.7	**57.2**	**62.2**				
AEMI	**25.5**	71.2	**80.3**				
TVCE	34.0	**59.7**	91.7				
LBAR	48.6	130.7	207.5				
BAMD	35.9	79.8	131.1				
BAMM	39.5	91.8	158.8				
BAMS	49.1	92.6	159.7				
Forecasts	5	3	1				

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Barbara, 28-30 May 2013. 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	72	96	120
OFCL	**5.0**	**10.0**	**5.0**				
OCD5	10.6	19.3	15.0				
Forecasts	5	3	1				
OFCL (2008-12)	6.3	10.5	13.4	14.5	15.3	17.0	17.3
OCD5 (2008-12)	7.6	12.5	16.5	18.8	20.4	20.3	20.6

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Barbara, 28-30 May 2013. 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	5.0	10.0	5.0				
OCD5	10.6	19.3	15.0				
GHMI	10.6	16.0	6.0				
HWFI	13.4	22.7	15.0				
DSHP	8.6	16.7	**4.0**				
LGEM	9.6	20.0	**0.0**				
ICON	10.2	18.3	**4.0**				
IVCN	10.2	18.3	**4.0**				
Forecasts	5	3	1				

Table 5. Watch and warning summary for Mexico in association with Hurricane Barbara, 28-30 May 2013.

Date/Time (UTC)	Action	Location
28 / 2100	Tropical Storm Warning issued	Lagunas de Chacahua to Boca de Pijijiapan
29 / 0900	Tropical Storm Warning modified to	Puerto Angel to Boca de Pijijiapan
29 / 0900	Hurricane Watch issued	Puerto Angel to Barra de Tonalá
29 / 1025	Hurricane Watch changed to Hurricane Warning	Puerto Angel to Barra de Tonalá
29 / 1000	Tropical Storm Warning modified to	Barra de Tonalá to Boca de Pijijiapan
30 / 0000	Tropical Storm Warning modified to	Salina Cruz to Boca de Pijijiapan
30 / 0000	Hurricane Warning discontinued	All
30 / 0600	Tropical Storm Warning modified to	Salina Cruz to Barra de Tonalá
30 / 0900	Tropical Storm Warning discontinued	All

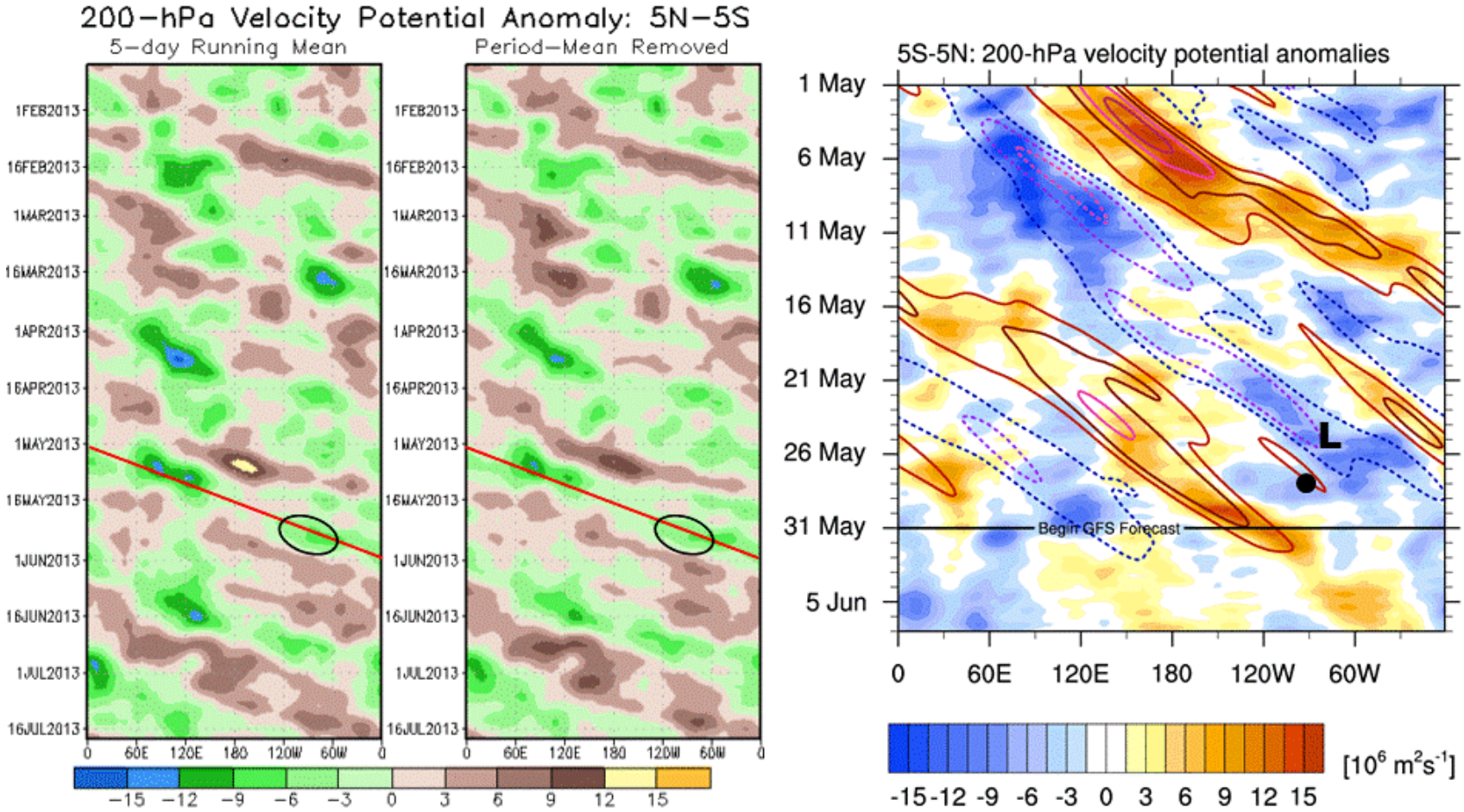

Figure 1. Hovmöller diagrams of 200 mb velocity potential anomalies from 5°N to 5°S (left two diagrams) showing the propagation of the Madden Julian Oscillation across the globe. The MJO wave associated with the development of Barbara is shown by the red slanted line with the eastern portion of the east Pacific basin highlighted in the black circle. The right Hovmöller diagram shows 200 mb velocity potential from 5°N to 5°S in color shading, with the Kelvin-filtered waves in dashed contours (courtesy Michael Ventrice). The dashed blue contours in the top left portion of the diagram that slants to the bottom right part of the figure shows the propagation of the convectively coupled Kelvin wave that played a role in the development of Barbara. The formation time and location of the incipient low pressure area from which Barbara developed is denoted by the “L” symbol and the location and time of tropical cyclone genesis is indicated by the black dot.

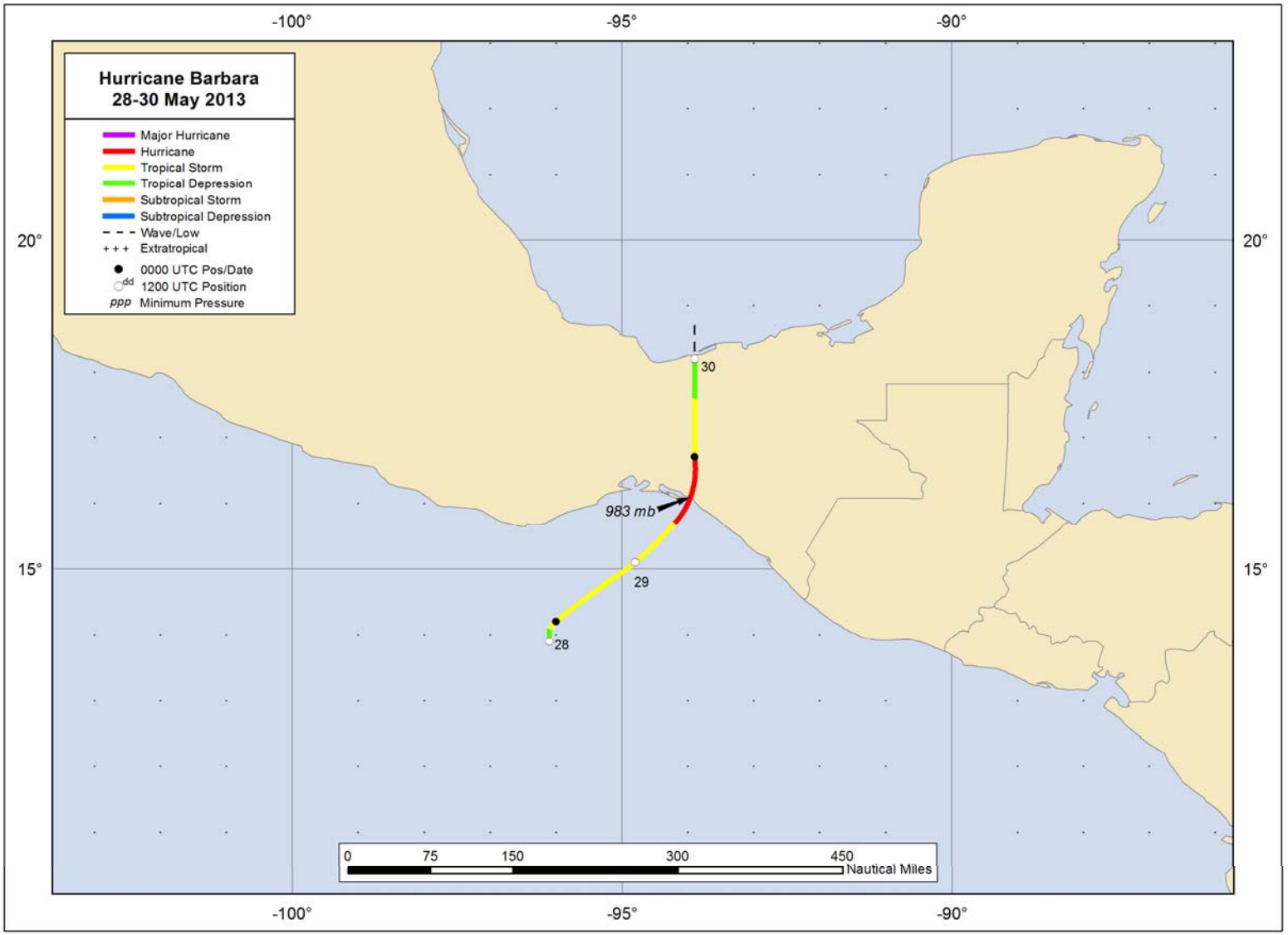

Figure 2. Best track positions for Hurricane Barbara, 28-30 May 2013.

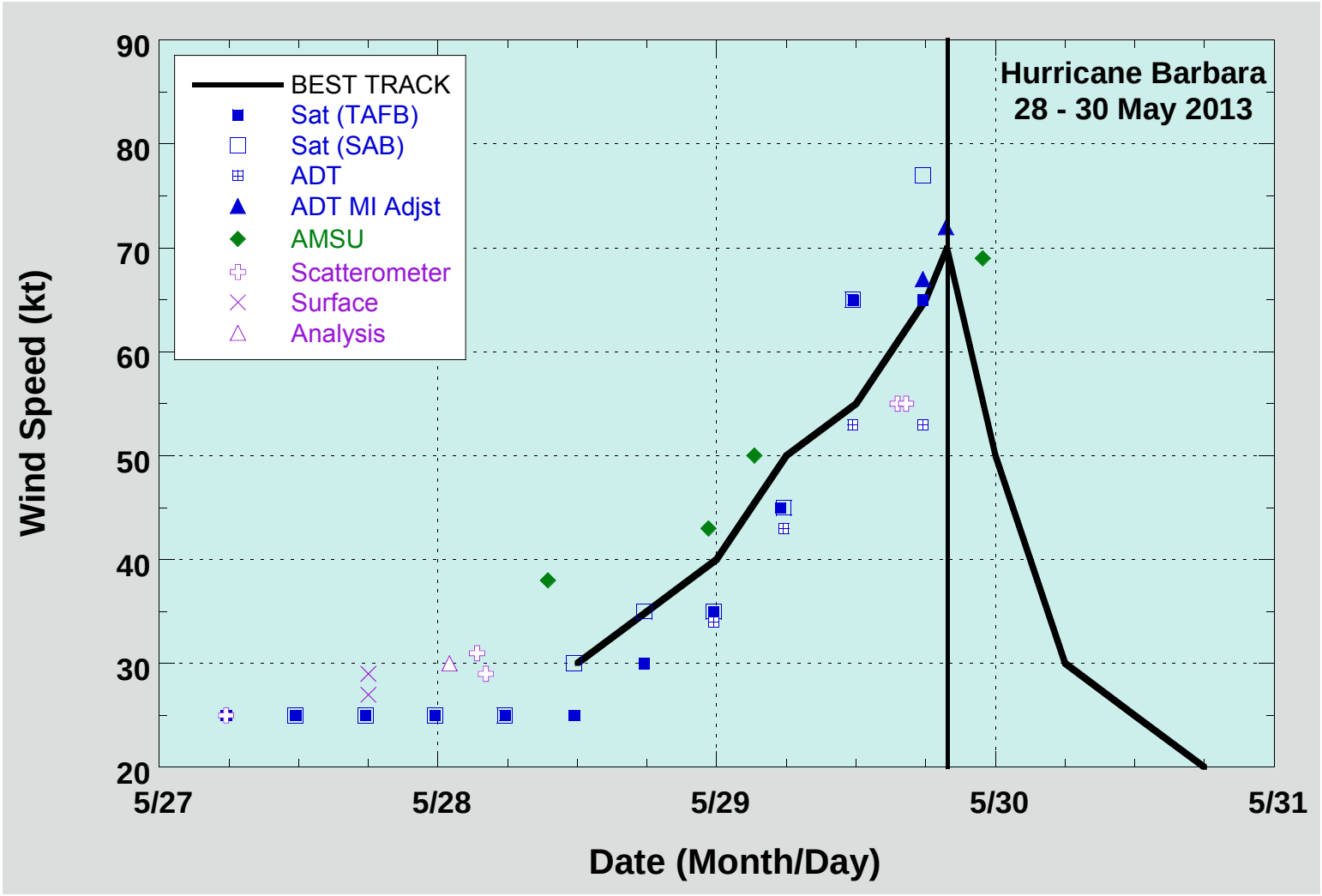

Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Barbara, 28-30 May 2013. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. Microwave data adjusted ADT estimates (blue triangle) represent ADT estimates that were adjusted in post-analysis (see Meteorological Statistics section of this report for more details). AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

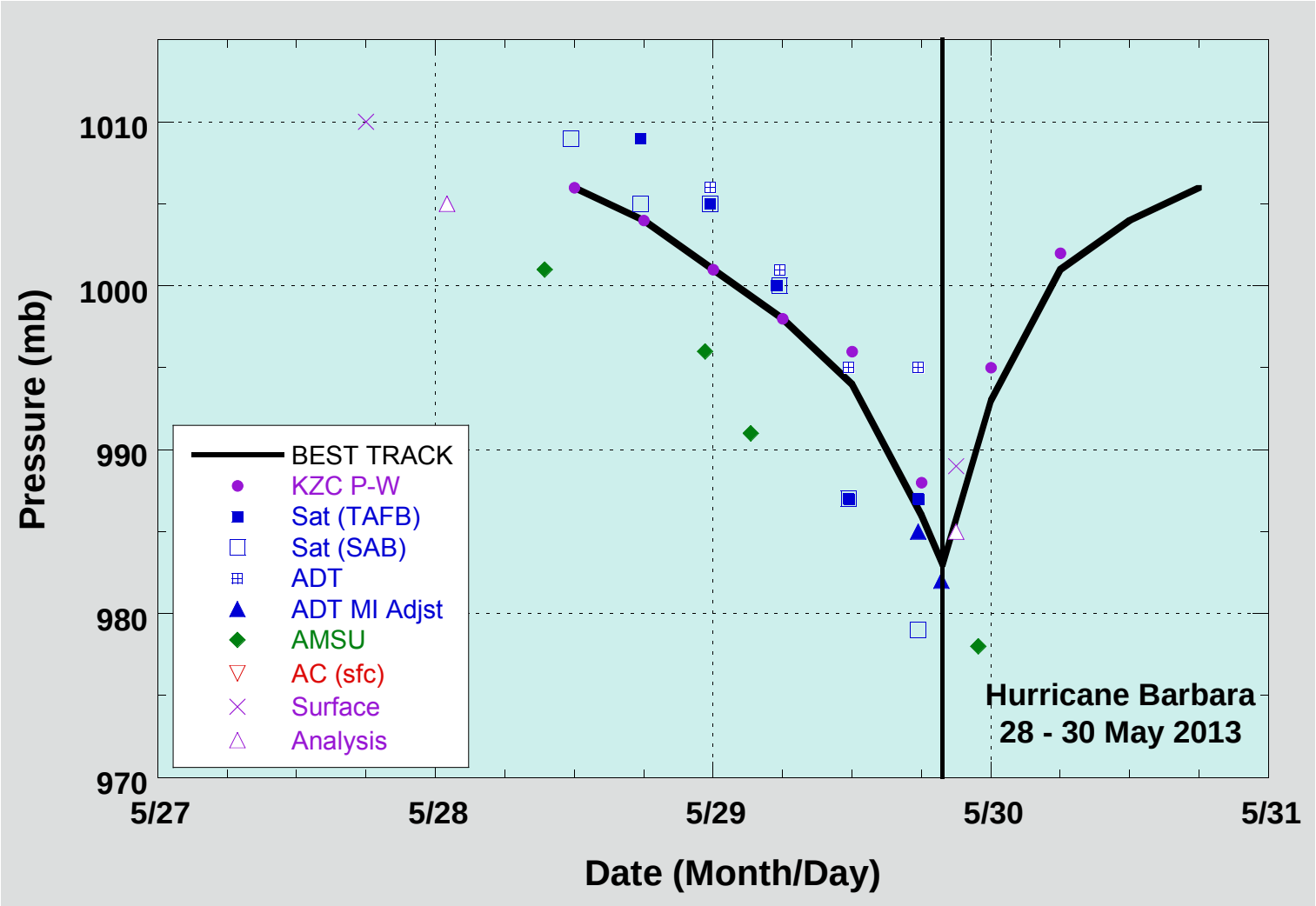

Figure 4. Selected pressure observations and best track minimum central pressure curve for Hurricane Barbara, 28-30 May 2013. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. Microwave data adjusted ADT estimates (blue triangle) represent ADT estimates that were adjusted in post-analysis (see Meteorological Statistics section of this report for more details). AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

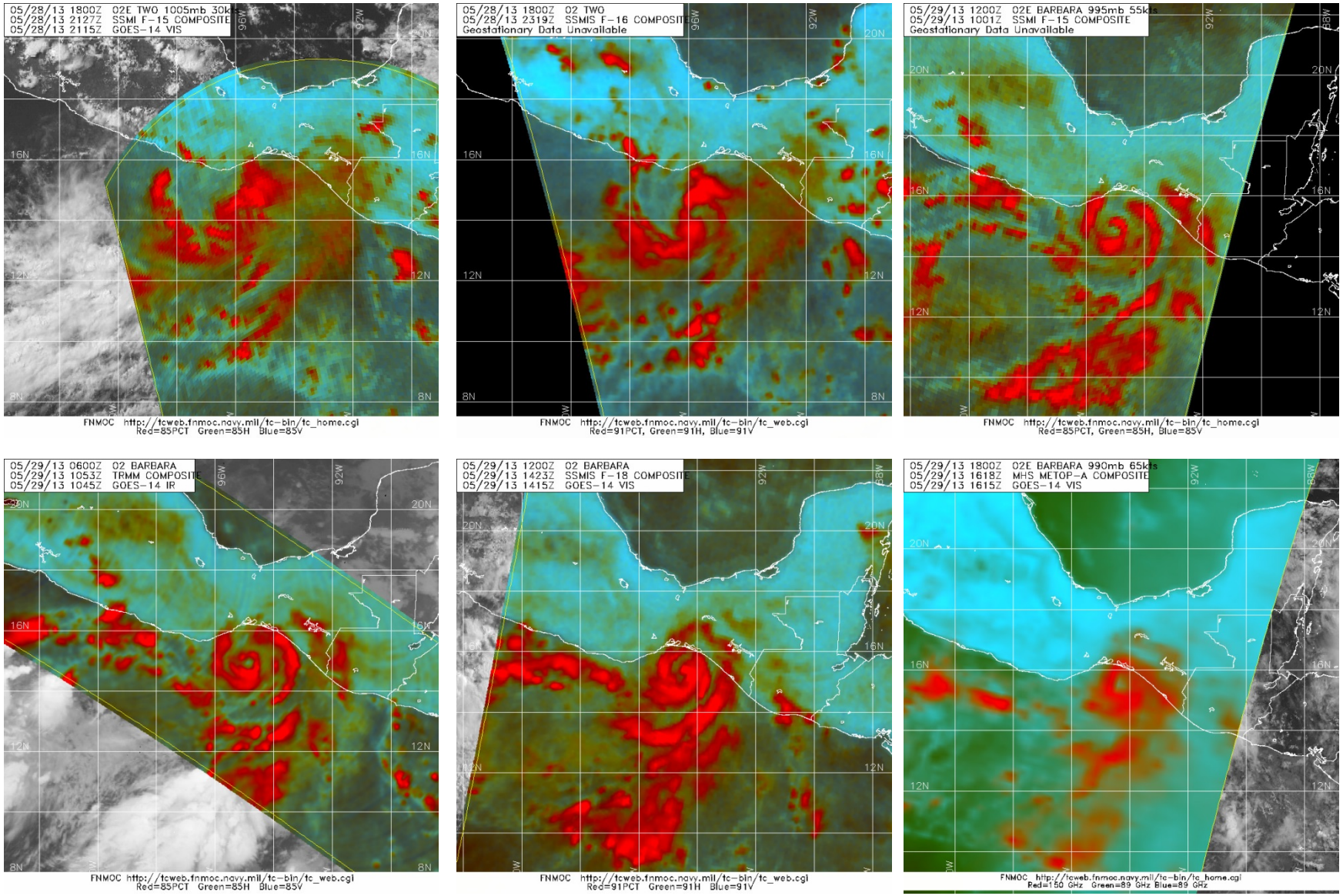

Figure 5. Composite 85 to 91 GHz microwave images showing the increasing organization of the inner core structure of Barbara from 2127 UTC 28 May (top left) to 1618 UTC 29 May (bottom right). Note the formation of the closed eye feature in the 1053 UTC 29 May image (bottom left). Images courtesy of the Naval Research Laboratory.

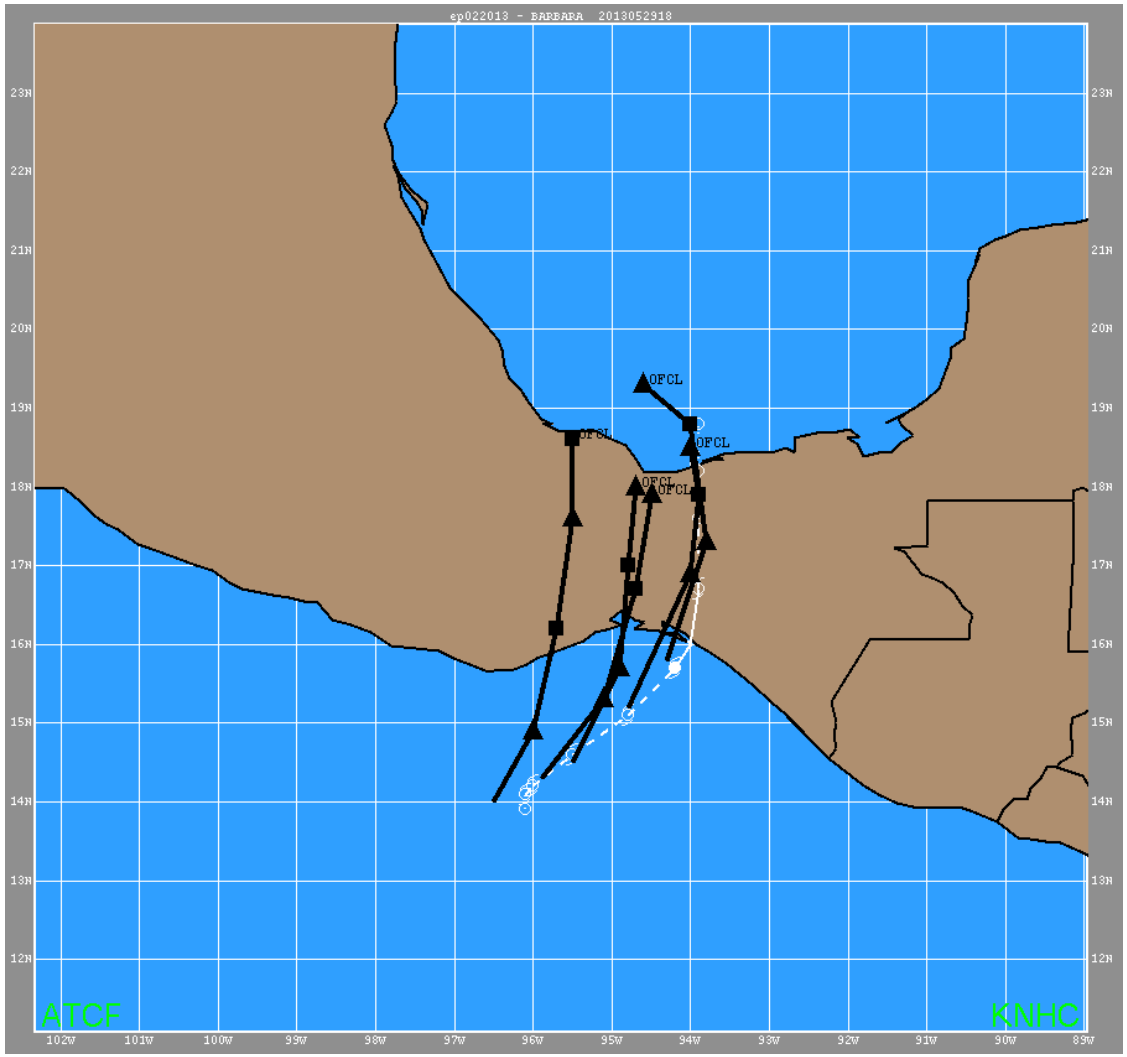

Figure 6. NHC official track forecasts (black) for Barbara between 1800 UTC 28 May and 1800 UTC 29 May. Note that the first few NHC forecasts anticipated Barbara's landfall occurring farther west than what actually occurred. The best track is given by the white line with positions shown at 6 h intervals.