NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM CARLOS

(EP032021)

12–16 June 2021

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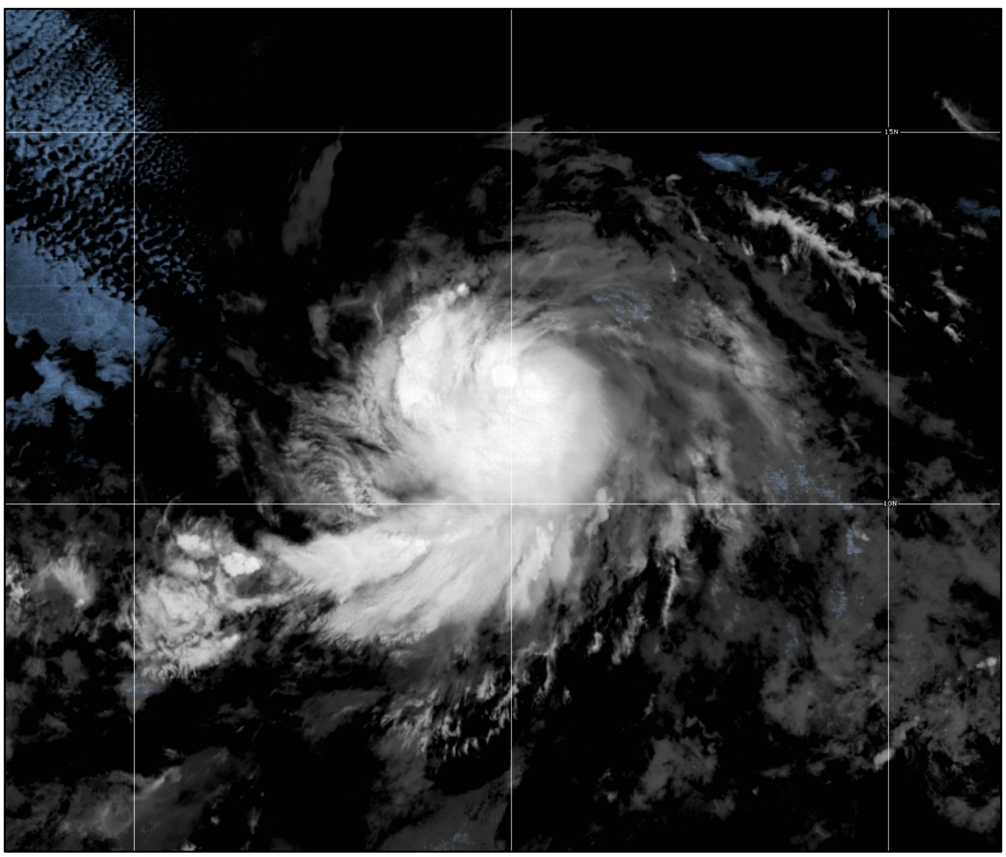
14 December 2021



GOES-17 GEOCOLOR SATELLITE IMAGE OF TROPICAL STORM CARLOS AT 0900 UTC 13 JUNE 2021, DURING THE TIME OF ITS PEAK INTENSITY. IMAGE COURTESY OF NOAA/NESDIS STAR.

Carlos was a relatively short-lived tropical storm in the eastern Pacific that did not affect any land areas.

Tropical Storm Carlos

12–16 JUNE 2021

SYNOPTIC HISTORY

The disturbance from which Carlos formed was first identified as a trough of low pressure along the Intertropical Convergence Zone (ITCZ) on 1 June. The initial disturbance appears to have formed in situ within monsoonal-like flow that was established over the far eastern Pacific basin during the latter portion of May. The trough moved westward at around 15 kt, enhancing convection along the ITCZ well south of the southern coast of Mexico. On 4 June, showers and thunderstorms increased in association with the trough, and a broad area of low pressure developed by 1200 UTC that day about 475 n mi south-southwest of Manzanillo, Mexico. The next day, the convective activity began showing signs of organization, but scatterometer wind data indicated that the circulation remained broad and ill defined. Early on 6 June, a cluster of convection developed over the northwestern portion of the broad circulation, and Dvorak classifications from both the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB) at 1200 UTC 6 June suggested the system had enough convective organization to be designated as a tropical cyclone. However, short-wave infrared and early-light visible satellite imagery still showed that the circulation was elongated and lacked a well-defined center; therefore, the system had not yet become a tropical cyclone. The deep convection began to wane that morning, but it briefly redeveloped around 0000 UTC 7 June. Shortly thereafter, the convective burst became well separated from the center of a low-level cloud swirl that was apparent in satellite imagery. Although that burst of deep convection resulted in the formation of a well-defined center, deep convection continued to wane and lose organization due to the entrainment of a drier and more stable airmass.

The low, located about 585 n mi south of the southern tip of the Baja California Peninsula, initially moved slowly westward, but turned southwestward on 8 June and produced occasional puffs of convection during the next couple of days over the far western portion of its circulation. The thermodynamic environment remained unfavorable for development, and the circulation of the low became elongated on 10 June as it became reinvolved with the eastern Pacific ITCZ. Later that day, a large burst of deep convection formed, which resulted in the formation of a well-defined mid-level circulation. That feature then continued westward with another burst of convection developing around midday, and by 0000 UTC 12 June the system again acquired a well-defined surface circulation. Deep convection continued to become better organized overnight, resulting in the formation of a tropical depression about 975 n mi southwest of the southern tip of the Baja California Peninsula by 1200 UTC 12 June. The system strengthened into a tropical storm 6 h later. The “best track” chart of Carlos’ 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].

Carlos moved just north of due west during the first 12 to 24 h of its existence within an environment of low vertical wind shear while over sea surface temperatures of 27–28°C. Consequently, the tropical cyclone strengthened, reaching a peak intensity of 45 kt by 0600 UTC 13 June (cover photo). Carlos was a small tropical cyclone with tropical-storm-force winds extending no more than 30 n mi from the center. Although the system was small, microwave satellite imagery around the time of peak intensity revealed a low-level eye-like feature and a curved band of convection over the southern and southwestern portions of the circulation (Fig. 4). By 1200 UTC 13 June, Carlos slowed down and began moving just south of due west as the low- to mid-level ridge originally to the north of the system repositioned farther west, resulting in a more northerly steering flow. Later that day, the tropical cyclone began to ingest drier mid-level air located just to its north, which resulted in a loss of convective organization and weakening by 0000 UTC 14 June. Carlos briefly became devoid of deep convection early on 14 June, but new convection redeveloped overnight, and the system maintained tropical storm status while moving west-southwestward. As the overall organization of the system waned later that day, Carlos gradually weakened, and it became a tropical depression by 1800 UTC 14 June when it was located about 1325 n mi west-southwest of the southern tip of the Baja California Peninsula. Bursts of deep convection continued in association with the depression over the next 36 h, and Carlos maintained tropical cyclone status while it moved west-southwestward at around 10 kt. By 1200 UTC 16 June, the system was no longer producing enough organized deep convection to be classified as a tropical cyclone, and Carlos degenerated into a remnant low about 1675 n mi west-southwest of the southern tip of the Baja California Peninsula. The remnant low moved west-southwestward to southwestward and was absorbed into the ITCZ about 1750 n mi southwest of the southern tip of the Baja California Peninsula shortly after 0000 UTC 17 June.

METEOROLOGICAL STATISTICS

Observations in Carlos (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

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[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.

Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Carlos.

The estimated 45-kt peak intensity of Carlos from 0600–1800 UTC 13 June is based on several ASCAT overpasses that revealed peak winds of around 40 kt just prior to both 0600 UTC and 1800 UTC that day. Given the typical under-sampling and low bias of the ASCAT instrument for tropical cyclones that possess a small radius of maximum winds (RMW), the peak winds are estimated to have been around 45 kt. That estimate is also supported by a blend of the subjective Dvorak estimates from TAFB and SAB and peak UW/CIMSS ADT estimates of T3.1 (47 kt). The 1003-mb estimated minimum pressure is based on the Knaff-Zehr-Courtney pressure-wind relationship, which was higher than the typical Dvorak pressure-wind relationship for this small low-latitude tropical cyclone.

There were no ship reports of winds of tropical storm force in association with Carlos.

CASUALTY AND DAMAGE STATISTICS

There were no reports of damage or casualties associated with Carlos.

FORECAST AND WARNING CRITIQUE

Despite seemingly long lead times of the NHC genesis probabilities, the development of Carlos was not well predicted. The system was initially introduced in the Tropical Weather Outlook (TWO) with a 5-day low (<40%) chance of development more than 9 days before formation occurred (Table 2). The system's 5-day development potential was raised to the medium (40–60%) category 8.25 days before formation and the high (>70%) category 7.75 days before development. The system was first assigned a 48-h low probability of formation 8.75 days before genesis, and it reached the medium and high categories 7.75 days and 7 days before genesis, respectively. The unusually long lead time was the result of the expectation that Carlos would form much sooner than what occurred. The system's 48-h and 5-day development potential reached 90% at 0600 UTC 6 June, just before the system nearly became a tropical cyclone (see Synoptic History section above). Genesis, however, did not occur, and the subsequent loss of organization and expected increase in vertical wind shear resulted in the decrease of the system's genesis probabilities beginning at 0000 UTC 7 June. Once formation did not occur on 6–7 June, it was believed that unfavorable upper-level winds and a surrounding dry and stable airmass would prevent further development of the relatively small disturbance. In addition, it was predicted that the weakening system would be absorbed into the eastern Pacific ITCZ rather than remain discrete. Therefore, the chance of formation was lowered to the medium category at 1200 UTC 7 June and to the low category at 0000 UTC 8 June. The disturbance was removed from the TWO at 1800 UTC 8 June when genesis was not thought to be possible.

The system was reintroduced into the TWO at 1200 UTC 10 June with a low chance of formation during both the 2- and 5-day periods when there was some increase in model support for genesis. This was only 48 h before development occurred (Table 2). The 5-day probability was raised to the medium category 6 h later, and the 48-h genesis potential was increased to the medium category 18 h before formation occurred. Neither the 5-day nor the 48-h probabilities reached the high category before genesis occurred on 12 June.

A verification of NHC official track forecasts for Carlos is given in Table 3a. Official forecast track errors were much larger than the mean official errors for the previous 5-yr period. Mean track errors from 36 to 72 h were 3 to 4 times larger than the long-term mean, albeit for a small sample size due to the short lifespan of Carlos. The OCD5 errors were also larger than their 5-yr means suggesting that the track forecasts for Carlos were more difficult than average. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. Most of the track guidance also exhibited unusually large mean forecast errors for Carlos. The best-performing individual track models were the HWFI, CMCI, and NVGI models, which all had mean errors about one-third of the size of the remainder of the guidance and the NHC forecasts. The consensus aids also had large mean errors, but most of them bested the official forecast at most lead times.

A bifurcation of the dynamical model guidance (Fig. 5) during the early portion of the lifecycle of Carlos resulted in unusually challenging track forecasts. Several of the dynamical models and their ensemble means (Fig. 5) predicted that Carlos would turn sharply northward in the 2- to 3-day period. Instead, Carlos weakened more quickly and moved west-southwestward within the low-level steering flow. Figure 6 shows the first four NHC forecasts compared to the remainder of the official track predictions. The large errors in those initial forecasts contributed to the much larger-than-normal mean track errors.

A verification of NHC official intensity forecasts for Carlos is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The best-performing intensity models were the HWFI and HMNI models with the HWFI besting the official forecast at all verifying lead times. Several of the consensus models also had slightly lower mean errors than the official forecast. The NHC intensity forecasts accurately predicted that Carlos would not significantly strengthen, but the first few forecasts did not anticipate that Carlos would begin to weaken as soon as it did.

There were no coastal watches or warnings issued in association with Carlos.

Table 1. Best track for Tropical Storm Carlos, 12–16 June 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
12 / 0000	11.2	120.3	1009	25	low
12 / 0600	11.4	121.3	1009	25	"
12 / 1200	11.6	122.3	1008	30	tropical depression
12 / 1800	11.8	123.3	1007	35	tropical storm
13 / 0000	11.9	124.2	1005	40	"
13 / 0600	11.9	125.0	1003	45	"
13 / 1200	11.8	125.7	1003	45	"
13 / 1800	11.7	126.3	1003	45	"
14 / 0000	11.6	126.9	1005	40	"
14 / 0600	11.4	127.7	1006	35	"
14 / 1200	11.2	128.6	1006	35	"
14 / 1800	10.9	129.5	1007	30	tropical depression
15 / 0000	10.5	130.4	1007	30	"
15 / 0600	10.2	131.3	1007	30	"
15 / 1200	10.0	132.2	1007	30	"
15 / 1800	9.9	133.1	1007	30	"
16 / 0000	9.6	133.9	1007	30	"
16 / 0600	9.2	134.5	1007	30	"
16 / 1200	8.8	134.9	1008	25	low
16 / 1800	8.5	135.3	1008	25	"
17 / 0000	8.4	135.8	1008	25	"
17 / 0600					dissipated
13 / 0600	11.9	125.0	1003	45	Maximum winds and minimum pressure

Table 2. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. The timings for the "Low" category do not include forecasts of a 0% chance of genesis. Note that the system was removed from the NHC Tropical Weather Outlook at one point before genesis, and the numbers inside the parentheses are the lead times in the indicated categories once the system was reintroduced into the Outlook at 1200 UTC 10 June.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	210 (48)	222 (48)
Medium (40%-60%)	186 (18)	198 (42)
High (>60%)	168 (-)	186 (-)

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Carlos, 12–16 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	25.0	55.7	109.8	180.9	272.8	370.1		
OCD5	34.9	84.5	144.9	204.0	257.8	321.4		
Forecasts	13	11	9	7	5	3		
OFCL (2016-20)	21.3	33.1	44.0	54.6	78.4	76.0	95.9	116.6
OCD5 (2016-20)	33.1	69.4	107.8	147.0	186.4	219.7	280.2	342.0

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Carlos, 12–16 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	33.1	77.9	126.2	189.7	274.6	387.5		
OCD5	44.6	95.5	147.5	196.2	**250.5**	**314.4**		
GFSI	40.4	82.2	128.0	205.8	304.9	477.5		
HMNI	33.4	**67.5**	**96.1**	**147.8**	**190.3**	**316.4**		
HWFI	34.9	**61.0**	**75.7**	**71.3**	**46.6**	**89.6**		
EGRI	42.0	81.7	135.7	**169.9**	**194.3**	**160.0**		
EMXI	**20.3**	**41.7**	**68.1**	**126.4**	**217.9**	**352.3**		
NVGI	**25.1**	**25.2**	**27.5**	**47.3**	**85.4**	**107.3**		
CMCI	**18.2**	**20.5**	**34.8**	**66.0**	**79.5**	**103.5**		
AEMI	34.8	**72.6**	**110.3**	**158.1**	**225.8**	**368.9**		
HCCA	**32.2**	**66.8**	**98.7**	**137.1**	**156.5**	**255.7**		
FSSE	**27.6**	**57.7**	**89.4**	**159.8**	**237.9**	**361.6**		
TVCX	**28.6**	**58.5**	**90.4**	**135.6**	**178.5**	**247.3**		
GFEX	**28.7**	**61.8**	**95.1**	**162.6**	**249.2**	410.6		
TVCE	**29.5**	**63.4**	**96.5**	**138.6**	**177.4**	**241.5**		
TVDG	**30.6**	**65.6**	**101.6**	**149.2**	**198.5**	**271.6**		
TABD	42.0	112.0	200.1	259.2	339.8	432.3		
TABM	33.3	**65.0**	**112.8**	**153.9**	**223.9**	**351.7**		
TABS	**21.7**	**25.7**	**49.0**	**97.0**	**146.2**	**168.1**		
Forecasts	6	6	6	4	3	1		

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Carlos, 12–16 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	**3.8**	**5.0**	**8.9**	**10.7**	**11.0**	**11.7**		
OCD5	5.2	7.9	11.8	16.4	27.0	24.0		
Forecasts	13	11	9	7	5	3		
OFCL (2016-20)	5.6	9.0	10.9	12.6	15.2	15.3	16.0	16.7
OCD5 (2016-20)	7.2	12.0	15.3	17.6	17.9	20.4	21.2	20.8

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Carlos, 12–16 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	3.8	5.0	9.4	11.7	11.0	11.7		
OCD5	5.2	7.9	13.1	19.0	27.0	24.0		
GFSI	4.0	6.7	**8.6**	12.3	14.4	21.7		
HMNI	4.2	6.5	**6.5**	**7.2**	**7.8**	**5.7**		
HWFI	**3.3**	**1.7**	**2.2**	**5.0**	**5.2**	**6.3**		
DSHP	4.8	9.3	13.1	14.0	13.4	16.0		
LGEM	4.7	8.4	10.9	11.3	**8.6**	**8.0**		
ICON	**3.7**	6.1	**7.6**	**9.3**	**8.6**	**9.0**		
IVCN	**3.7**	6.1	**7.6**	**9.3**	**8.6**	**9.0**		
IVDR	**3.5**	5.5	**6.9**	**8.7**	**9.0**	**10.3**		
HCCA	3.9	6.7	10.5	11.8	10.2	**10.3**		
Forecasts	13	11	8	6	5	3		

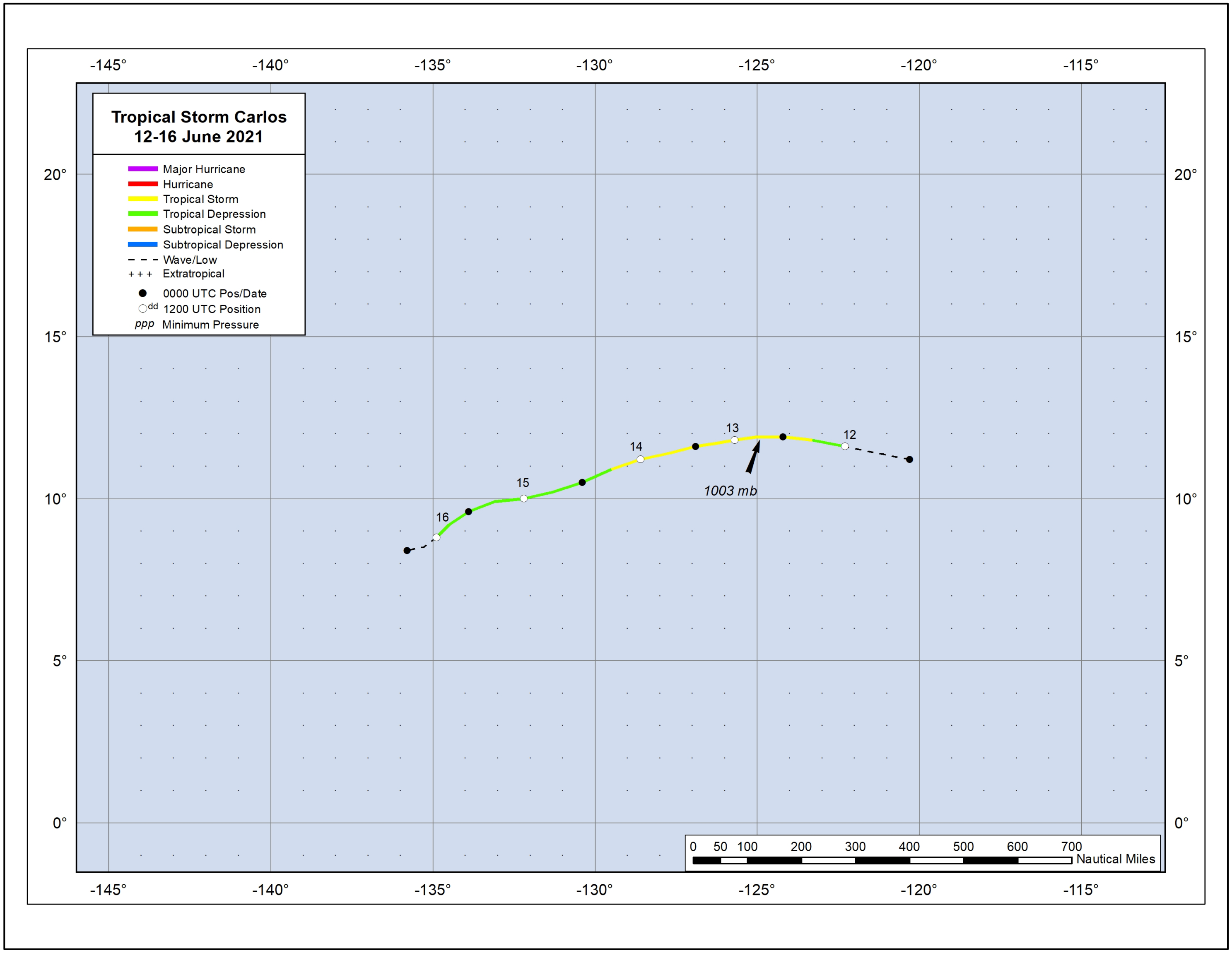

Figure 1. Best track positions for Tropical Storm Carlos, 12–16 June 2021.

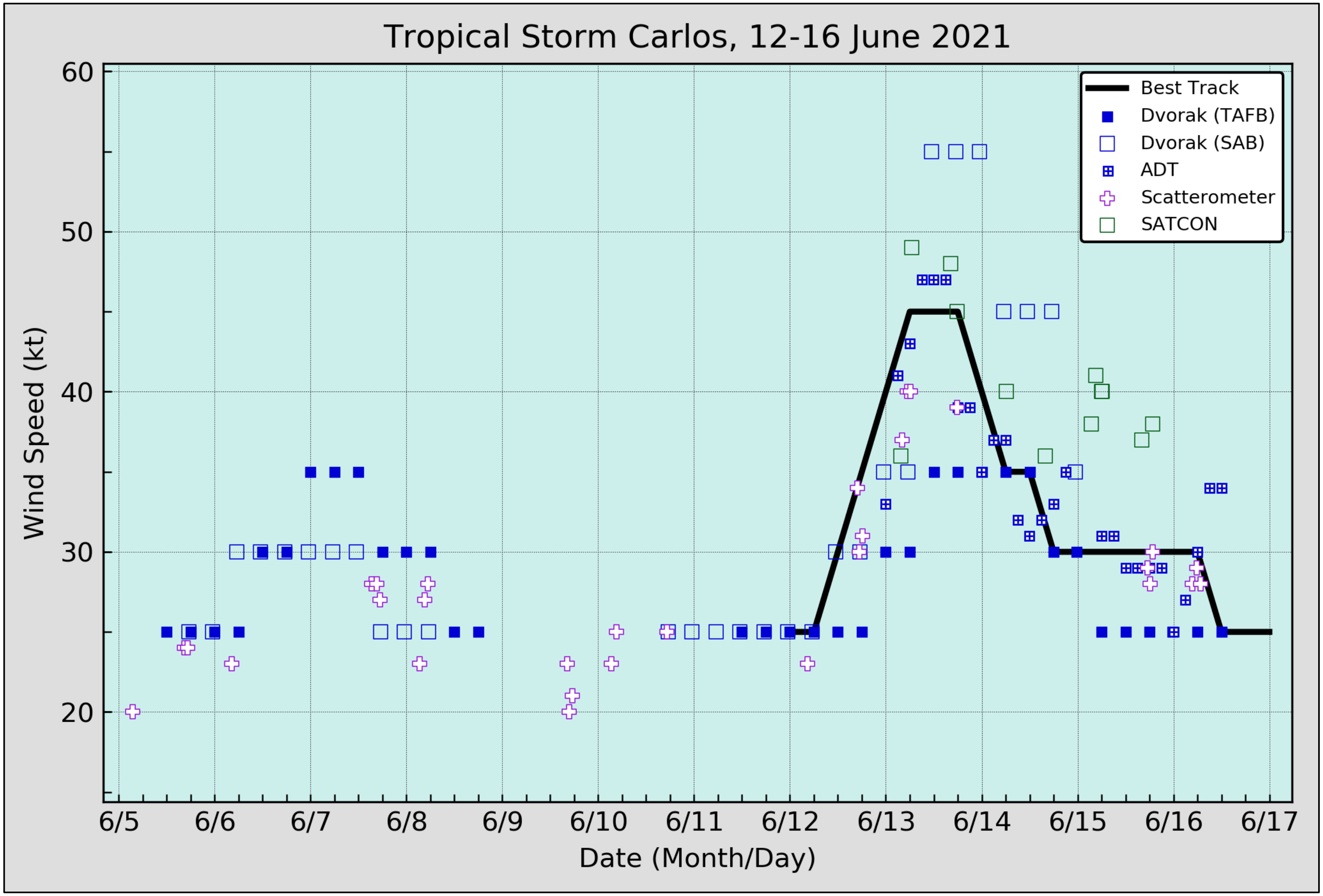

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Carlos, 12–16 June 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

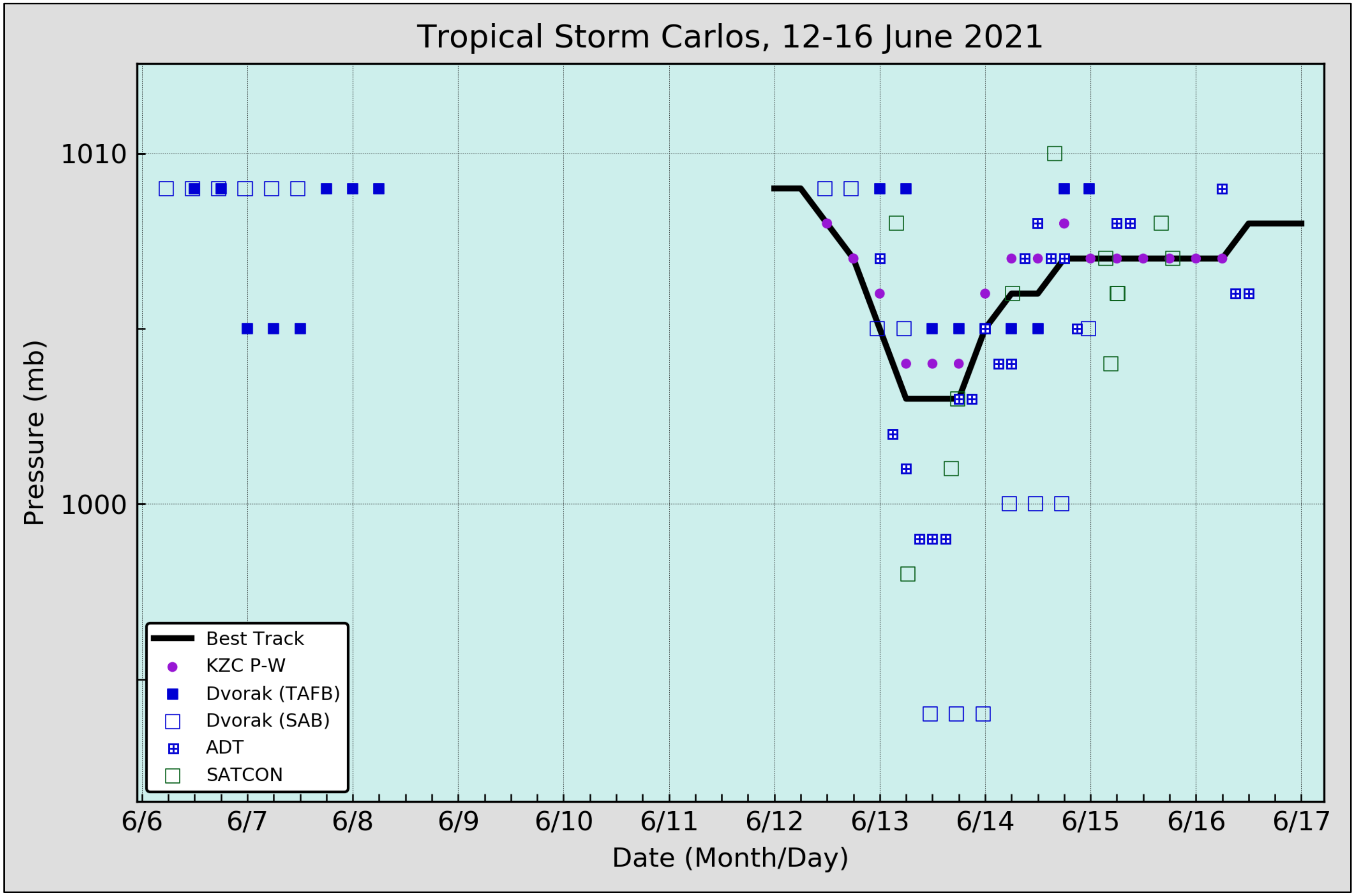

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Carlos, 12–16 June 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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.

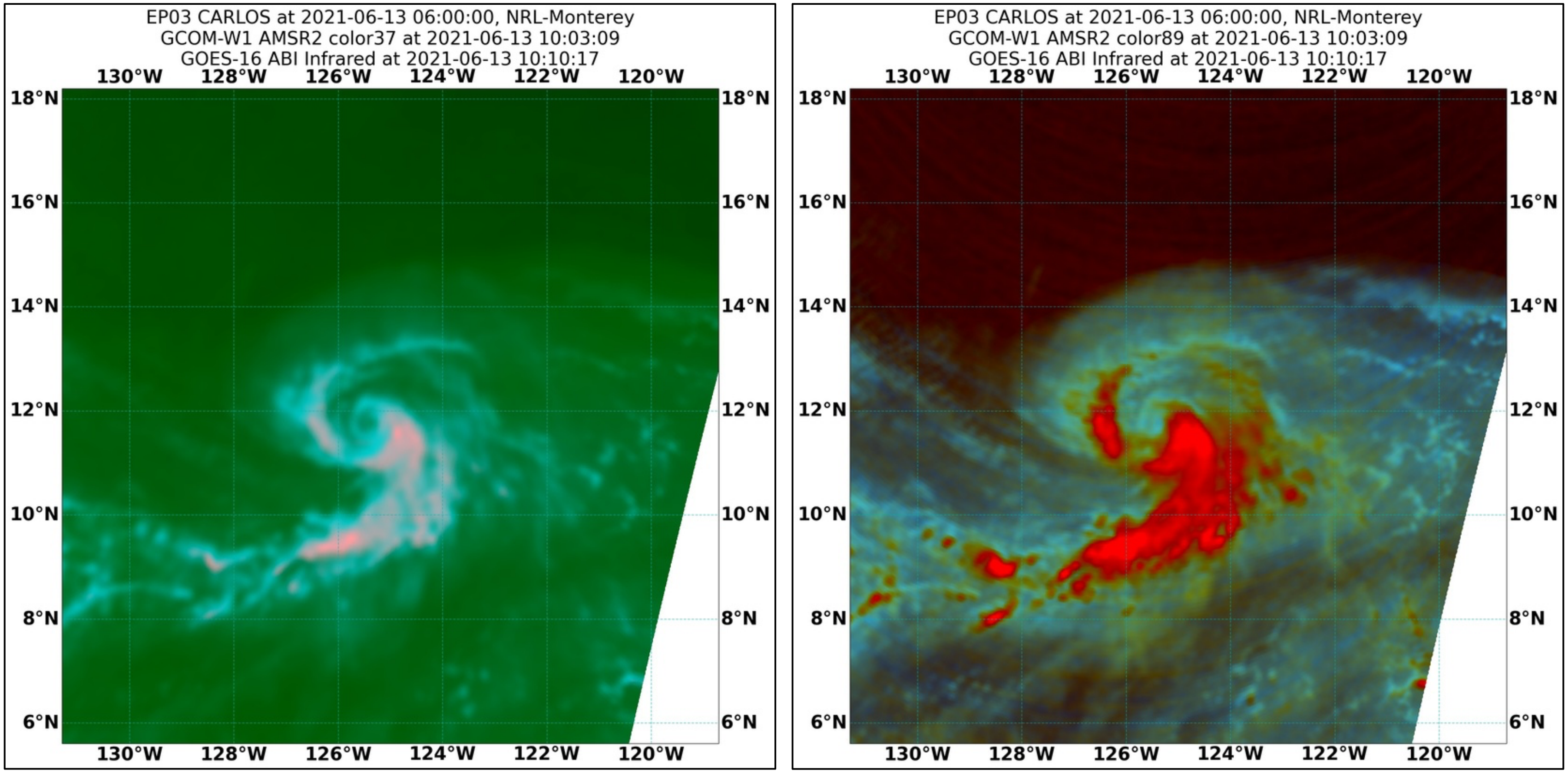

Figure 4. AMSR2 37-GHz (left) and 89-GHz (right) color composite microwave images of Tropical Storm Carlos at 1010 UTC 13 June around the time of the system's peak intensity. Images courtesy U.S. Naval Research Laboratory, Monterey, California.

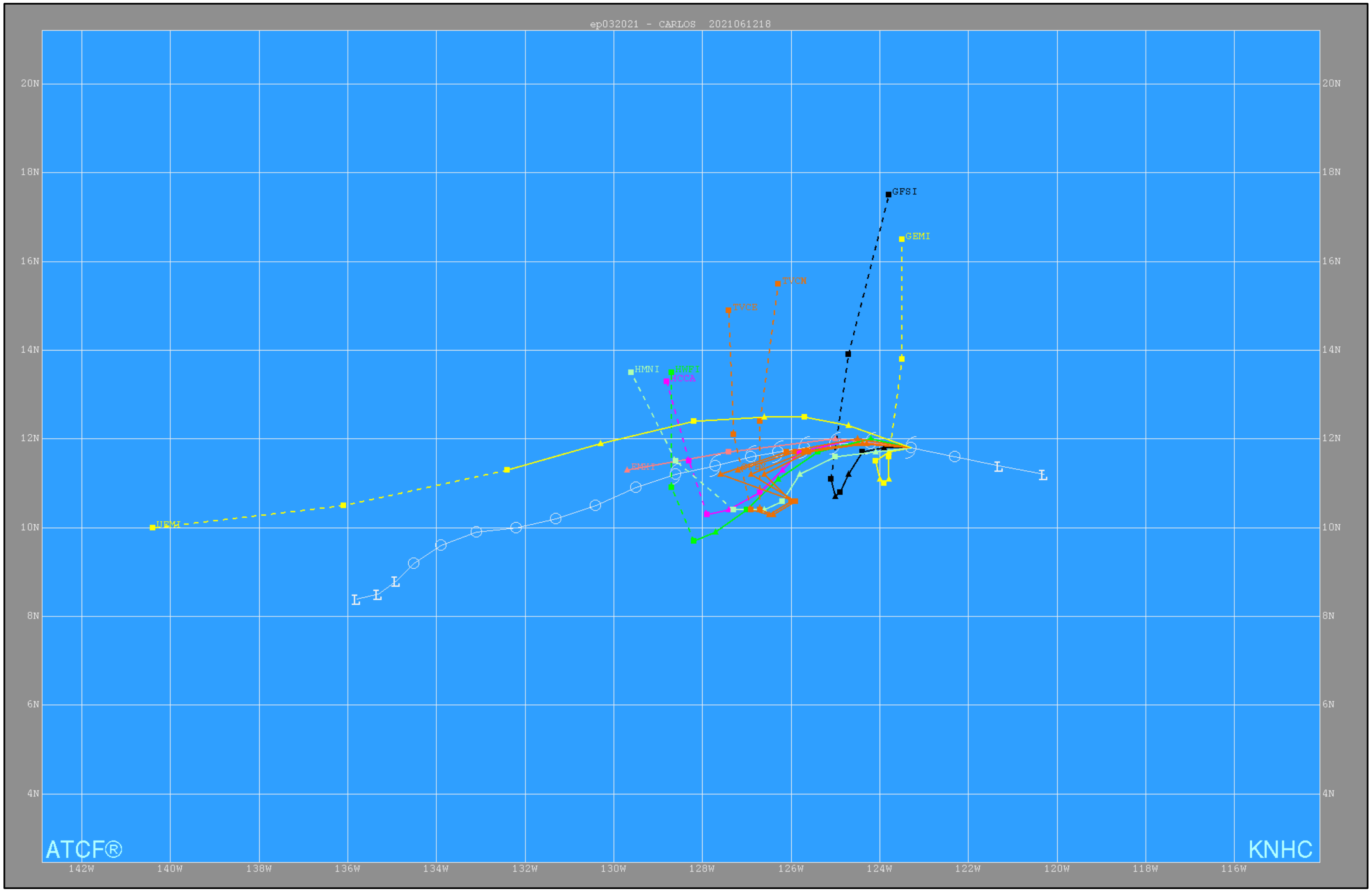

Figure 5. Selected track model guidance for the first NHC advisory issued on Carlos at 1800 UTC 12 June. Note the sharp northward turn predicted by several of the models in the 48–72-h period.

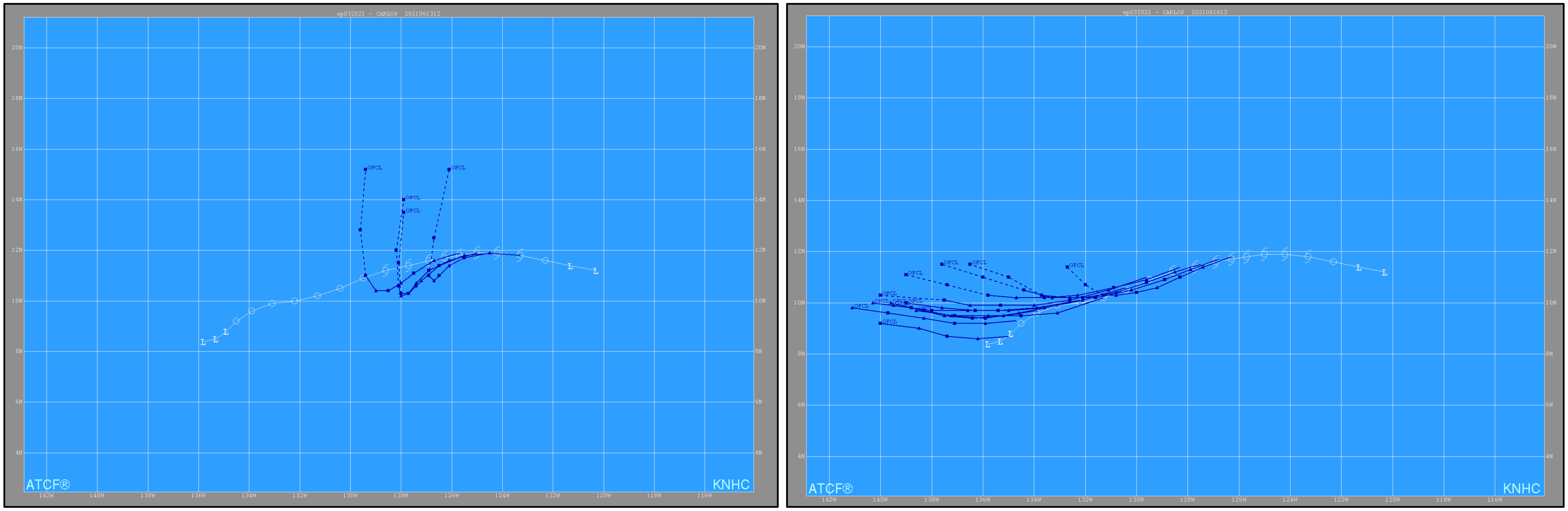

Figure 6. The first four NHC official track forecasts (left) and the remaining official track forecasts (right) for Tropical Storm Carlos 12–16 June 2021. Note the northward bias in the first four NHC forecasts as compared to the remainder of the track forecasts for Carlos. The actual track of Carlos is denoted by the white symbols plotted at 6-h intervals.