NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE MARCO

(AL142020)

21–25 August 2020

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National Hurricane Center
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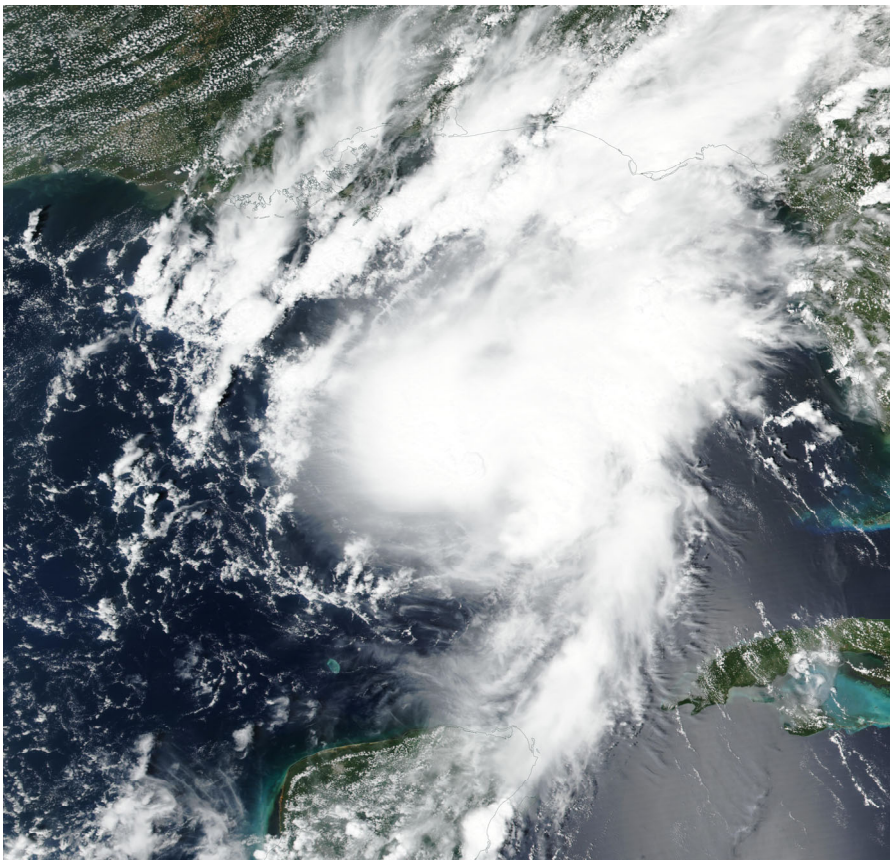

SUOMI/NPP VIIRS IMAGE OF MARCO AT 1842Z 23 AUGUST 2020. IMAGE COURESY OF NASA WORLDVIEW.

Marco formed over the western Caribbean Sea, became a hurricane for a few hours over the Gulf of Mexico, and dissipated over water south of the Louisiana coast.

Hurricane Marco

21–25 AUGUST 2020

SYNOPTIC HISTORY

Marco developed from a tropical wave that moved westward from the coast of Africa on 10–11 August. The initial associated convection was poorly organized, and it gradually decreased in coverage by 15 August as the wave moved over the central tropical Atlantic. After that time, the convection gradually increased when the wave moved over the western tropical Atlantic. The wave passed through the Lesser Antilles on 17 August, accompanied by disorganized convection and showing no signs of a closed circulation. The convection first showed signs of organization on 19 August, and a broad low-pressure area formed that day over the central Caribbean Sea. Gradual development continued on 20 August as the low moved generally westward toward Central America. By 0600 UTC 21 August, there was a closed circulation and sufficient organized convection for the system to be considered a tropical depression over the extreme western Caribbean Sea about 25 n mi northeast of Cabo Gracias a Dios, on the border of Nicaragua and Honduras. 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].

The depression was moving west-northwestward at the time of genesis. A turn toward the northwest took place a few hours later as the cyclone approached a weakness in the subtropical ridge caused by an upper-level trough over the western Gulf of Mexico. This motion kept the center of the developing cyclone just offshore of the coasts of Nicaragua and Honduras. Intensification began later on 21 August and the depression became a tropical storm near 0000 UTC 22 August as it turned north-northwestward over the northwestern Caribbean Sea. Continued strengthening led to Marco reaching an intensity of 55 kt as the center moved through the Yucatan Channel into the southeastern Gulf of Mexico late on 22 August. A second period of strengthening caused Marco to become a hurricane for 6–12 h over the southeastern Gulf of Mexico on 23 August, with a peak intensity of 65 kt. At that time, Hurricane Hunter aircraft reported an eye as small as 4 n mi in diameter.

Soon thereafter, increasing southwesterly upper-level winds caused by the aforementioned trough led to the small cyclone shearing apart and quickly weakening, with the system becoming a tropical storm again later on 23 August while centered about 230 n mi south-southeast of the mouth of the Mississippi River. The center became exposed southwest of the deep convection on 24 August, and a turn toward the west occurred that day as a low-level ridge to the north of the now vertically shallow cyclone became the predominant steering influence. The center passed just south of the mouth of the Mississippi River around 0000 UTC 25 August,

[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.

and just after that time Marco weakened to a depression. Deep convection never re-formed near the center, and the cyclone degenerated to a remnant low and then to a trough south of the Louisiana coast later that day.

METEOROLOGICAL STATISTICS

Observations in Marco (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 Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from nine missions of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command and three synoptic surveillance missions flown by the NOAA Aircraft Operations Center's G-IV aircraft. 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 Marco.

Selected surface observations from land stations, oil rigs, and data buoys are given in Table 2.

It should be noted that in real time the center of Marco was judged to have made landfall at the mouth of the Mississippi River near 2300 UTC 24 August based on satellite imagery showing a low-cloud swirl over land. However, data from stations at the Southwest Pass of the Mississippi River suggest that the actual wind and pressure center stayed just south of those stations and that landfall did not occur. It should also be noted that operationally the National Hurricane Center (NHC) began advisories on the tropical depression that became Marco at 1500 UTC 20 August. However, post-storm analysis, including aircraft and scatterometer observations, indicates that the system instead became a tropical depression near 0600 UTC 21 August.

Winds and Pressure

During their nine missions, the 53rd Weather Reconnaissance Squadron made 33 center fixes. The maximum flight-level wind observed was 70 kt at 700 mb at 1523 UTC 23 August, and the maximum surface wind estimate from the SFMR was 69 kt at the same time. These data, as well as winds from a dropsonde in the northeastern eyewall at 1117 UTC 23 August (64 kt at the surface and an average of 75 kt over the lowest 150 m), support a peak intensity of 65 kt. The lowest aircraft-reported pressure was 991 mb extrapolated from 850 mb at 1121 UTC 23 August.

Marco likely caused tropical-storm conditions over portions of the Cuban province of Pinar del Rio as the center passed about 45 n mi west of Cabo San Antonio at the western tip of the island. The strongest wind reported from this area was a 36-kt gust at Cabo San Antonio.

In the United States, there were two observations of sustained tropical-storm-force winds. The first was 34 kt with a gust to 40 kt at the elevated (20 m) National Ocean Service (NOS) station at the Southwest Pass of the mouth of the Mississippi River. The second was 48 kt with a gust to 65 kt at the elevated (35 m) Tyndall Tower Coastal-Marine Automated Network (C-MAN) station located south of the coast of the Florida Panhandle. The latter observation was likely due to a severe thunderstorm occurring well to the northeast of the center of Marco. A few wind gusts to tropical-storm force were reported along sections of the Alabama and Mississippi coasts.

At sea, the container ship *Barbara* (call sign CQDT) reported 50-kt winds (anemometer elevation unknown) and a pressure of 1006.0 mb near the center of Marco at 1800 UTC 22 August. This was the only ship report of tropical-storm-force winds from the cyclone, and it is the highest known surface wind from Marco. The *Visoca Knoll* oil platform (call sigh KVOA) reported sustained winds of 46 kt at 1520 UTC 24 August with a peak gust of 51 kt at an elevation of 160 m.

Storm Surge[2]

Marco produced peak storm surge inundation levels of 1 to 2 ft above ground level along the coasts of southeastern Louisiana, Mississippi, Alabama, and the Florida Panhandle (Table 2, Fig. 6). Slightly higher inundation of 2 to 3 ft above ground level may have occurred near Lake Pontchartrain, Lake Maurepas, and Lake Borgne outside of the Hurricane and Storm Damage Risk Reduction System (HSDRSS). Within that area, a NOS tide gauge at the Bonnet Carre Floodway along Interstate 10 measured an unverified peak water level of 2.8 ft above Mean Higher High Water (MHHW). The largest measured departure from normal tides was 3.26 ft above normal tide levels at an NOS tide gauge at Shell Beach, Louisiana; combined with the tide, this resulted in a peak water level of 2.5 ft Mean Higher High Water (MHHW) at that station. A peak water level of 2.4 ft MHHW was also measured at the New Canal Station NOS gauge in New Orleans outside of the HSDRSS. It should be noted that some of these peak water levels were recorded on 25 August after Marco had become a remnant low, but before Hurricane Laura raised water levels more significantly along the northern Gulf coast during the ensuing couple of days.

Outside of Lake Pontchartrain, maximum water levels recorded by NOS tide gauges were all less than 2 ft MHHW and include 1.8 ft MHHW at Pilot's Station East, Louisiana; 1.8 ft MHHW at Bay Waveland Yacht Club, Mississippi; 1.6 ft MHHW at Dauphin Island and Bayou La Batre Bridge, Alabama; and 1.6 ft MHHW at Pensacola, Florida.

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[2] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

Rainfall and Flooding

In Cuba, Marco caused rainfalls of 2–5 inches (50–125 mm) over the province of Pinar del Rio, with a maximum storm total rainfall of 5.72 inches (145.3 mm) at Cabo San Antonio.

In the United States, Marco caused rainfall totals of 3–5 inches with locally heavier amounts along portions of the Gulf coasts of Florida, Alabama, and Mississippi (Table 3 and Figure 7). The maximum reported rainfall total was 13.17 inches near Apalachicola, Florida. These rains caused localized minor flooding. Locally heavy rainfalls also occurred over portions of southern Louisiana during the 23–25 August period. However, it is unclear that these rains were directly related to Marco and thus they are not included in Table 3.

Tornadoes

There were no known tornadoes associated with Marco.

CASUALTY AND DAMAGE STATISTICS

There were no reports of casualties associated with Marco. Winds associated with the storm caused minor damage in western Cuba, and rains over the southeastern United States also caused minor damage due to flooding.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Marco was generally well forecast (Table 3), with the potential for development first noted in the Tropical Weather Outlook (TWO) as a low chance (<40%) in the 5- day range 126 h before genesis occurred. The chances in the 5-day range were increased to medium (40–60%) 108 h before genesis occurred and to high (>60%) 60 h before formation. The forecasts in the 2-day range were somewhat less good. The system was first mentioned with a low chance 126 h before genesis, with the chances being raised to medium 54 h before genesis and high 30 h before genesis. Overall, the genesis forecasts correctly anticipated that the pre-Marco wave would be slow to develop over the tropical Atlantic and the eastern Caribbean, and that conditions would be more favorable in the western Caribbean.

Track

A verification of NHC official track forecasts for Marco is given in Table 4a, with the individual track forecasts shown in Fig. 4. Official forecast track errors were significantly greater than the mean official errors for the previous 5-yr period. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. Several of the track guidance models had lower average errors than the official forecasts at several of the forecast

times, including the consensus models TVCA and HCCA and the U.S. Navy dynamical models NAVGEM (NGVI) and COAMPS-TC (CTCI). Examination of the individual official forecasts shows that many of them had a significant westward bias, forecasting a northwestward motion while Marco instead moved toward the north-northwest. This may have been due to the combined impact of several guidance models underestimating how much Marco would develop and underestimating the effects of the southwesterly upper-level flow on the track of Marco until the storm sheared apart. It should be noted that the NAVGEM had the strongest depiction of Marco, and its good performance is likely related to this.

Intensity

A verification of NHC official intensity forecasts for Marco is given in Table 5a, with the individual intensity forecasts shown in Fig. 5. Official forecast intensity errors were greater 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 5b. As with the track forecasts, several of the intensity guidance models had lower errors than the official forecasts, including the consensus models ICON, IVCN, and IVDR and the dynamical COAMPS-TC and Hurricanes in a Multi-scale Ocean-coupled Non-hydrostatic model (HMNI). Examination of the individual official forecasts suggest two sources of error. First, many of the forecasts underestimated how quickly Marco would weaken in the strong shear environment over the northern Gulf of Mexico. Second, several of the early track forecasts incorrectly called for Marco to cross the northeastern Yucatan Peninsula, which caused them to show weakening due to the land interaction.

Wind Watches and Warnings

Tropical cyclone wind watches and warnings associated with Marco are given in Table 6a. In Central America and Mexico, Tropical Storm Watches and Warnings were issued for portions of the coasts of Nicaragua and Honduras, while a Tropical Storm Warning and a Hurricane Watch were issued for portions of the coast of the Yucatan Peninsula of Mexico. These watches and warnings were discontinued when it became apparent that the core of Marco would stay offshore of those areas. In Cuba, a Tropical Storm Warning was issued for the province of Pinar del Rio on 22–23 August. In an unusual circumstance, during part of this time the province was also under a Tropical Storm Watch for Tropical Storm Laura approaching from the east.

In the United States, many watches and warnings were issued for the northern Gulf Coast, including a Hurricane Warning issued at 0900 UTC 23 August. Once it became apparent that Marco had sheared apart and was rapidly weakening, these warnings were stepped down and eventually discontinued.

Storm Surge Forecasts and Warnings

Storm surge watches and warnings associated with Marco area given in Table 6b and depicted in Fig. 8. Because Marco was forecast to reach the northern Gulf coast as a hurricane, a Storm Surge Watch was issued from Sabine Pass to the Alabama/Florida border, including Lake Pontchartrain, Lake Maurepas, Lake Borgne, and Mobile Bay at 2100 UTC 22 August. A portion of the watch area was upgraded to a Storm Surge Warning from Morgan City, Louisiana, to Ocean Springs, Mississippi, including Lake Borgne, at 0900 UTC 23 August. Since Marco was a minimal tropical storm instead of a hurricane when it passed near the mouth of the Mississippi

River, storm surge inundation of 3 ft or greater above normally dry ground (which NHC uses as a first-cut threshold for the storm surge watch/warning) did not occur along the northern Gulf coast. Thus, the Storm Surge Warning did not verify.

The initial storm surge inundation forecast issued at 2100 UTC 22 August was 3 to 5 ft above normally dry ground somewhere between Grand Isle, Louisiana, and the Alabama/Florida border, including Lake Borgne and Mobile Bay. Inundation of 2 to 4 ft above ground level was expected elsewhere between Sabine Pass and Grand Isle, as well as Lake Pontchartrain and Lake Maurepas. When the Storm Surge Warning was issued at 0900 UTC 23 August, the inundation forecast was increased to 4 to 6 ft above normally dry ground somewhere between Morgan City, Louisiana, and Ocean Springs, Mississippi, including Lake Borgne. As with the Storm Surge Warning, these inundation forecasts did not verify since Marco weakened significantly before approaching the coast, and maximum inundation levels were less than 3 ft above ground level.

Impact-Based Decision Support Services (IDSS) and Public Communication

The NHC was in communication with emergency managers during the time that Marco posed a threat to the northern Gulf coast, and this continued after the storm dissipated due to the threat of Hurricane Laura. A full media pool was opened on 23 August to cover the threat of both Marco and Laura to the U.S. NHC provided eight Facebook Live broadcasts on 23–24 August discussing both storms with about 838,000 views of these videos. Note that the full media pool remained in operation after Marco dissipated to cover the ongoing threat of Hurricane Laura. The media pool closed on 27 August.

ACKNOWLEDGEMENTS

Data in Table 2 were compiled from Post Tropical Cyclone (PSH) Reports issued by the NWS Weather Forecast Offices (WFOs) in Mobile, Alabama, and Slidell and Lake Charles, Louisiana. Additional data were used from reports sent by the National Data Buoy Center and the NOS Center for Oceanographic Products and Services, as well as the Weatherflow, Mesowest, South Alabama, and Iowa Environmental Mesonet web sites. The Meteorological Service of Cuba provided data from that country. Dave Roth and Zack Taylor of the Weather Prediction Center provided the rainfall map and other rainfall data. Dennis Feltgen reported the media statistics used in this report, while Tiffany O'Connor contributed the IDSS report.

Table 1. Best track for Hurricane Marco, 21–25 August 2020.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
20 / 1800	14.1	80.5	1009	30	low
21 / 0000	14.6	81.8	1007	30	"
21 / 0600	15.3	82.9	1007	30	tropical depression
21 / 1200	16.3	83.7	1008	30	"
21 / 1800	17.4	84.2	1007	30	"
22 / 0000	18.3	84.6	1006	35	tropical storm
22 / 0600	19.2	85.1	1004	40	"
22 / 1200	20.3	85.2	993	55	"
22 / 1800	21.3	85.5	992	55	"
23 / 0000	22.2	86.1	994	55	"
23 / 0600	23.2	86.7	994	60	"
23 / 1200	24.3	87.2	991	65	hurricane
23 / 1800	25.3	87.4	992	65	"
24 / 0000	26.4	87.6	997	55	tropical storm
24 / 0600	27.3	87.9	1003	50	"
24 / 1200	28.1	88.3	1006	45	"
24 / 1800	28.7	88.6	1007	40	"
25 / 0000	28.9	89.3	1006	35	"
25 / 0600	28.7	90.5	1008	25	low
25 / 1200	28.6	91.4	1009	20	"
25 / 1800	29.1	92.3	1009	20	"
26 / 0000					dissipated
23 / 1200	24.3	87.2	991	65	maximum winds and minimum pressure

Table 2. Selected surface observations for Hurricane Marco, 21–25 August 2020.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Buoys									
42003 NOAA (25.93N 85.62W) (3.8m)	23/2130	1010.7	23/0831	32 (1-min)	35				
42012 NOAA (30.06N 87.55W) (3.8m)	25/0010	1011.9	24/1221	31 (1-min)	35				
42039 NOAA (28.79N 86.01W) (4.1m)	24/1100	1010.4	24/1201	34 (1-min)	39				
42040 NOAA (29.21N 88.23W) (3.8m)	24/1910	1010.1	24/1138	29 (1-min)	39				
42056 NOAA (19.82N 84.95) (3.8m)	22/1010	1005.4	22/1011	33 (1-min)	39				
Offshore Oil Platforms									
Main Pass 140B (KMIS) (29.23N 87.78W) (115m)	24/1935	1010.2	24/1655	35	41				
Viosca Knoll (KVOA) (29.23N 87.78W) (160m)	24/1920	1010.2	24/1520	46	51				
Main Pass 289C (KVKY) (29.30N 88.84W) (85m)	24/2115	1008.7	24/1855	31	40				
Cuba									
Cabo San Antonio (78310) (21.87N 84.95W)	22/2150	1008.8	22/2015	24	36				5.72
Isabel Rubio (78313) (22.17N 84.10W)	22/1700	1009.0	22/2230		22				4.17
Florida									
International Civil Aviation Organization (ICAO) Sites									
Destin (KDTS) (30.39N 86.47W)	24/2153	1012.9	23/1853		22				3.49

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Pensacola Rgnl. Arpt. (KPNS) (29.23N 87.78W)	24/2253	1012.9	23/2020	21	26				6.00
Coastal-Marine Automated Network (C-MAN) Sites									
Tyndall Tower (SGOF1) (30.38N 86.86W) (35m)	24/0700	1013.3	24/0610	48 (2-min)	65				
Public/Other									
Navarre Beach Marine Science Station (30.38N 86.86W)	24/2300	1010.8	24/0340	24	29				3.04
Remote Automated Weather Stations (RAWS)									
Naval Live Oaks (TR992) (30.37N 87.14W) (6.1m)			23/1200		21				5.16
NWS Cooperative Observer Program (COOP) Sites									
Chipley (CHPF1) (30.78N 85.48W)									4.70
Pensacola (PSAF1) (30.53N 87.20W)									5.12
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Fountain 3.4SSE (FL-BY-15) (30.43N 85.40W)									4.44
Panama City Beach 4.4ESE (FL-BY-22) (30.18N 85.79W)									7.47
Lynn Haven 1S (FL-BY-23) (30.24N 85.67W)									3.36
Cross City 4.7E (FL-DX-2) (29.64N 83.05W)									3.00

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Old Town 4.9NW (FL-DX-3) (29.66N 83.03W)									3.20
Gonzalez 2.1E (FL-ES-15) (30.57N 87.25W)									4.49
Pensacola 1.9NE (FL-ES-26) (30.47N 87.17W)									6.10
Pensacola Beach 4ENE (FL-ES-49) (30.42N 87.15W)									4.73
Apalachicola 0.8WNW (FL-FR-8) (29.73N 85.01W)									13.17
Eastpoint 5.8SEE (FL-FR-8) (29.67N 84.84W)									10.77
St. George Island 4.7ENE (FL-FR-10) (29.67N 84.84W)									7.50
Alfred 0.6SSE (FL-JK-2) (30.69N 85.39W)									4.80
Bronson 3SE (FL-LV-4) (29.42N 82.60W)									3.34
Niceville 4SE (FL-OK-1) (30.49N 86.44W)									3.61
Destin 1.2NW (FL-OK-33) (30.40N 86.49W)									3.01
Navarre 2.1WNW (FL-SR-12) (30.41N 86.90W)									3.88
Crawfordville 1S (FL-WK-10) (30.18N 84.37W)									3.81
Sunny Hills 3.3N (FL-WS-3) (30.59N 85.58W)									3.96
Freeport 3.4S (FL-WT-2) (30.45N 86.14W)									7.01

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Miramar Beach 9.5ESE (FL-WT-3) (30.35N 86.20W)									3.89
DeFuniak Springs 2.9N (FL-WT-12) (30.76N 86.12W)									3.76
Inlet Beach 0.7E (FL-WT-14) (30.28N 86.00W)									5.09
Alabama									
International Civil Aviation Organization (ICAO) Sites									
Mobile Bates Field (KMOB) (30.68N 88.07W)	25/1056	1012.7	23/2228	23	36				1.24
Coastal-Marine Automated Network (C-MAN) Sites									
Dauphin Island (DPIA1) (30.25N 86.08W) (14m)	25/0000	1012.1	25/1150	28 (10-min)	42				
National Ocean Service (NOS) Sites									
Dauphin Island (DILA1) (30.25N 88.08W) (10m)	25/0818	1011.9	25/1148	32	40	1.86	2.28	1.6	
Fort Morgan (FMOA1) (30.23N 88.03W) (38m)	24/2242	1011.9	25/1854	32	39				
South Alabama Mesonet									
Florala (31.00N 86.34W)									3.46
Gasque (30.24N 87.90W)									3.29
NWS Cooperative Observer Program (COOP) Sites									
Ashland 3ENE (ALDA1) (33.28N 85.79W)									4.68

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Atmore 12N (ATMA1) (31.17N 87.44W)									3.18
Geneva (GVAA1) (31.04N 85.87W)									3.10
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Elberta 3.1SSW (AL-BW-53) (30.37N 87.62W)									4.66
Gulf Shores 7.1WSW (AL-BW-92) (30.23N 87.81W)									3.62
Dauphin Island 4.8E (AL-MB-92) (30.25N 88.09W)									3.30
Jackson 4.3WSW (AL-WS-1) (31.51N 87.96W)									4.60
Mississippi									
International Civil Aviation Organization (ICAO) Sites									
McComb (KMCB) (31.18N 90.47W)									3.30
Laurel/Hattiesburg (KPIB) (31.47N 89.33W)									3.12
NOS Sites									
Pascagoula NOAA Lab (PNLM6) (30.37N 88.56W)						1.62	2.40	1.5	
Petit Bois (PTBM6) (30.21N 88.50W) (4.6m)	25/0030	1011.6	24/1824	29	35				
Waveland Yacht Club (WYCM6) (30.33N 89.33W) (9.9m)	25/0754	1012.0	24/2354		26	2.31	2.88	1.8	
Hydrometeorological Automated Data System (HADS) Sites (NWS)									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Caesar 3WSW (CREM6) (30.57N 89.59W)									5.39
D'Iberville 4N (DIBM6) (30.48N 88.90W)									6.52
Gulfport 6WNW (GLFM6) (30.40N 88.20W)									7.77
Kiln 2S (KLNM6) (30.39N 89.44W)									6.86
Lyman 4E (LYMM6) (30.48N 89.03W)									6.76
McNeil 3W (MNLM6) (30.66N 89.69W)									4.60
Orange Grove 3NNE (ORAM6) (30.46N 88.45W)									4,58
Advanced Hydrological Prediction Service (AHPS) Sites									
Graham Ferry (PGFM6) (30.61N 88.64W)									3.46
NWS Cooperative Observer Program (COOP) Sites									
Mize (MIZM6) (31.85N 89.55W)									4.25
Prentiss 3NW (PREM6) (31.62N 89.92W)									5.00
Sumrall (SMAM6) (31.42N 89.53W)									4.92
Waynesboro 2W (WAYM6) (31.68N 88.67W)									3.31
Louisiana									
NOS Sites									
Bonnet Carre (BCFL1) (30.07N 90.39W)							2.96*	2.8*	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
New Canal (NWCL1) (30.03N 90.11W) (9.9m)	25/0842	1010.2	25/0248	26	28	2.35	2.68	2.4	
Pilottown (PILL1) (29.18N 89.26W) (9.5m)	24/2318	1008.6	24/1936		30	1.55		1.0	
Southwest Pass (PSTL1) (28.93N 89.41W) (20m)	25/0012	1006.1	24/0454	34	40	1.70		1.8	
Shell Beach (SHBL1) (29.87N 89.67W) (16m)	25/0848	1011.1	24/2124	28	32	3.26	3.24	2.5	

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is water height above the North American Vertical Datum of 1988 (NAVD88).
[e] Estimated inundation is the maximum height of water above ground. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.
* Unverified

Table 3. Number of hours in advance of formation for Hurricane Marco 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%)	126	126
Medium (40%-60%)	54	108
High (>60%)	30	60

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Marco, 21–25 August 2020. 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	30.3	54.1	84.1	129.0	184.0	225.2		
OCD5	39.7	74.7	125.7	193.8	271.3	361.7		
Forecasts	14	12	10	8	6	4		
OFCL (2015-19)	24.1	36.9	49.6	65.1	80.7	96.3		
OCD5 (2015-19)	44.7	96.1	156.3	217.4	273.9	330.3		

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Marco, 21–25 August 2020. 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	31.2	55.9	85.9	129.0	184.0	223.3		
OCD5	41.9	74.9	128.6	193.8	271.3	**216.0**		
GFSI	39.4	74.9	111.1	155.8	218.4	280.9		
HWFI	35.6	61.9	104.7	140.7	181.1	**104.9**		
HMNI	37.3	64.8	90.0	**106.8**	**130.6**	**117.4**		
EMXI	32.3	**53.3**	**68.5**	**113.7**	**183.1**	244.5		
NVGI	**24.3**	**42.8**	**66.2**	**87.8**	**138.7**	**143.3**		
CMCI	44.2	89.5	149.2	239.2	396.5	422.4		
CTCI	34.3	**53.3**	**63.6**	**72.0**	**91.5**	**107.9**		
TVCA	32.6	**55.1**	**79.8**	**114.3**	**160.2**	**179.7**		
GFEX	33.5	60.1	88.0	132.1	198.9	260.6		
HCCA	33.4	56.6	**82.1**	**121.8**	**173.1**	**191.4**		
AEMI	37.1	67.7	104.1	146.2	201.2	**193.8**		
TABS	43.8	102.8	159.5	223.2	306.1	368.3		
TABM	35.0	63.5	98.4	147.7	216.8	226.9		
TABD	38.9	64.4	98.1	146.3	**166.7**	**80.3**		
Forecasts	12	10	9	8	6	2		

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Marco, 21–25 August 2020. 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	7.1	13.3	15.0	15.0	13.3	21.2		
OCD5	8.4	13.9	21.2	26.5	25.0	17.0		
Forecasts	14	12	10	8	6	4		
OFCL (2015-19)	5.2	7.7	9.4	10.7	11.9	13.0		
OCD5 (2015-19)	6.8	10.8	14.1	17.0	18.8	20.6		

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Marco, 20–25 August 2020. 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	6.2	11.5	14.4	15.0	13.3	21.2		
OCD5	7.5	12.0	19.4	26.5	25.0	**17.0**		
HMNI	**6.1**	**5.7**	**4.9**	**10.4**	**13.2**	25.2		
HWFI	10.0	15.5	15.2	**8.6**	**7.3**	26.0		
DSHP	8.1	13.6	19.2	20.9	18.7	**12.8**		
LGEM	7.8	13.8	21.3	24.1	21.8	**7.5**		
ICON	6.9	**7.7**	**11.1**	**10.5**	**11.8**	**18.0**		
IVCN	6.5	**8.4**	**11.1**	**10.5**	**11.3**	**16.8**		
IVDR	**6.1**	**7.4**	**9.6**	**8.0**	**9.2**	**15.8**		
CTCI	**5.3**	**10.4**	**13.8**	**11.1**	**10.0**	**9.2**		
GFSI	6.8	12.9	17.4	17.8	14.5	**4.2**		
EMXI	**5.6**	12.3	19.3	20.1	13.3	**5.0**		
HCCA	6.3	**8.0**	**11.8**	**7.0**	**10.0**	25.5		
Forecasts	12	10	9	8	6	4		

Table 6a. Tropical cyclone wind watch and warning summary for Hurricane Marco, 21–25 August 2020.

Date/Time (UTC)	Action	Location
20/1500	Tropical Storm Watch issued	Coast of Honduras from Punta Castilla to the Honduras/Nicaragua border, including the Bay Islands
20/2100	Tropical Storm Watch changed to Tropical Storm Warning	Coast of Honduras from Punta Castilla to the Honduras/Nicaragua border, including the Bay Islands
20/2100	Tropical Storm Warning issued	Coast of Nicaragua from Puerto Cabezas to the Honduras/Nicaragua border
21/0300	Hurricane Watch and Tropical Storm Warning issued	Coast of Mexico from Punta Herro to Cancun
21/1500	Tropical Storm Watch issued	Coast of Mexico north and west of Cancun to Dzilam
21/1500	Tropical Storm Warning discontinued	Coast of Nicaragua
21/1500	Tropical Storm Warning discontinued	Coast of Honduras from Punta Castilla to the Honduras/Nicaragua border
21/2100	Tropical Storm Watch changed to Tropical Storm Warning	Coast of Mexico north and west of Cancun to Dzilam
21/2100	Tropical Storm Warning discontinued	Bay Islands of Honduras
22/1500	Tropical Storm Warning issued	Cuban province of Pinar del Rio
22/1500	Hurricane Watch and Tropical Storm Warning discontinued	Coast of Mexico south of Cancun
22/2100	Hurricane Watch issued	Intracoastal City, Louisiana to the Mississippi/Alabama border, including Lake Pontchartrain, Lake Maurepas, and metropolitan New Orleans.

22/2100	Tropical Storm Watch issued	Mississippi/Alabama border to the Alabama/Florida border
22/2100	Tropical Storm Warning discontinued	Coast of Mexico
23/0900	Hurricane Warning issued	Coast of Louisiana from Morgan City to the mouth of the Pearl River
23/0900	Tropical Storm Warning issued	Lake Pontchartrain, Lake Maurepas, and metropolitan New Orleans.
23/0900	Hurricane Watch discontinued and Tropical Storm Warning issued	Mouth of the Pearl River to the Mississippi/Alabama border
23/0900	Tropical Storm Warning discontinued	Cuban province of Pinar del Rio
23/2100	Tropical Storm Warning issued	Louisiana coast west of Morgan City to Cameron
24/0300	Hurricane Watch discontinued	Louisiana coast west of Morgan City
24/0900	Hurricane Warning changed to Tropical Storm Warning	Coast of Louisiana from Morgan City to the mouth of the Pearl River
24/0900	Hurricane Watch discontinued	Lake Pontchartrain, Lake Maurepas, and metropolitan New Orleans.
24/0900	Tropical Storm Watch discontinued	Alabama coast and Louisiana coast west of Intracoastal City
24/1500	Tropical Storm Warning discontinued	Louisiana coast west of Morgan City
24/1800	All coastal warnings discontinued	

Table 6b. Storm surge watch and warning summary for Hurricane Marco, 21–25 August 2020.

Date/Time (UTC)	Action	Location
22/2100	Storm Surge Watch issued	Sabine Pass, Texas to the Alabama/Florida border, including Lake Pontchartrain, Lake Maurepas, Lake Borgne, and Mobile Bay
23/0900	Storm Surge Warning issued	Morgan City, Louisiana to Ocean Springs, Mississippi, including Lake Borgne
23/1500	Storm Surge Watch discontinued	Alabama coast including Mobile Bay
24/0900	All Storm Surge Watches discontinued	Louisiana coast west of Morgan City and Mississippi coast east of Ocean Springs
24/1800	All Storm Surge Warnings discontinued	

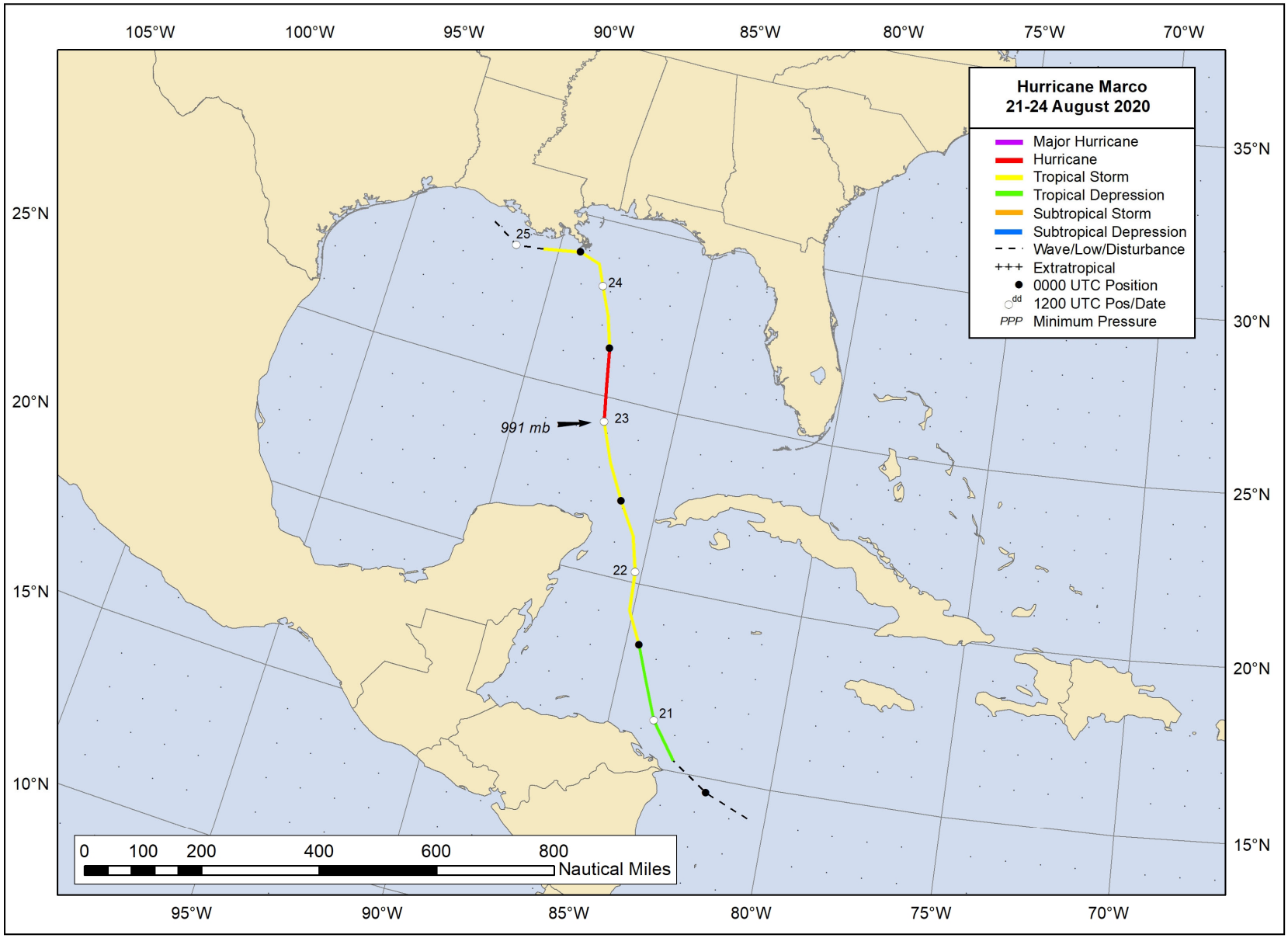

Figure 1. Best track positions for Hurricane Marco, 21–25 August 2020.

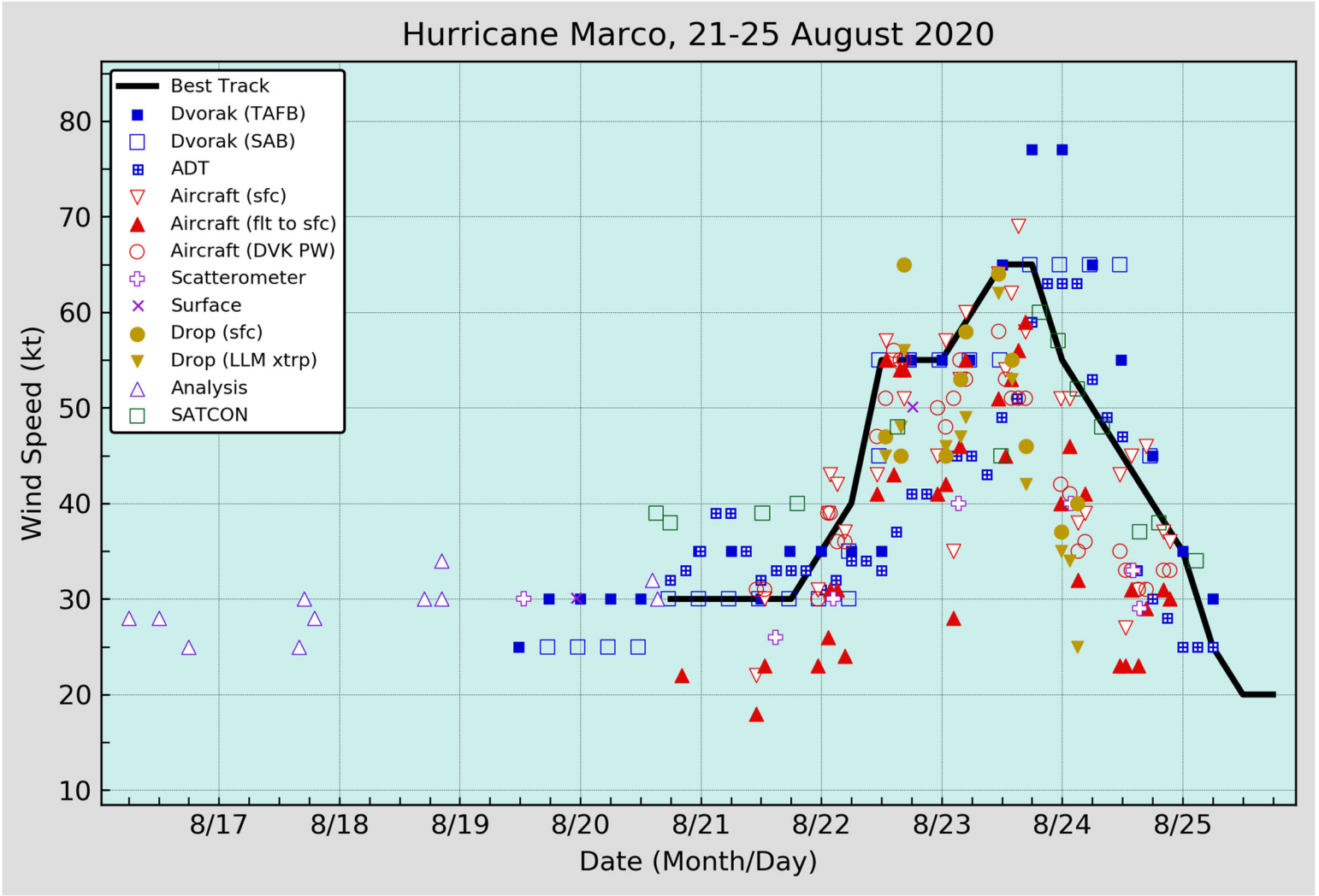

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Marco, 21–25 August 2020. Aircraft observations have been adjusted for elevation using 90%, 80%, 75%, and 80% adjustment factors for observations from 700 mb, 850 mb, 925 mb, and 1500 ft, respectively. 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 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.

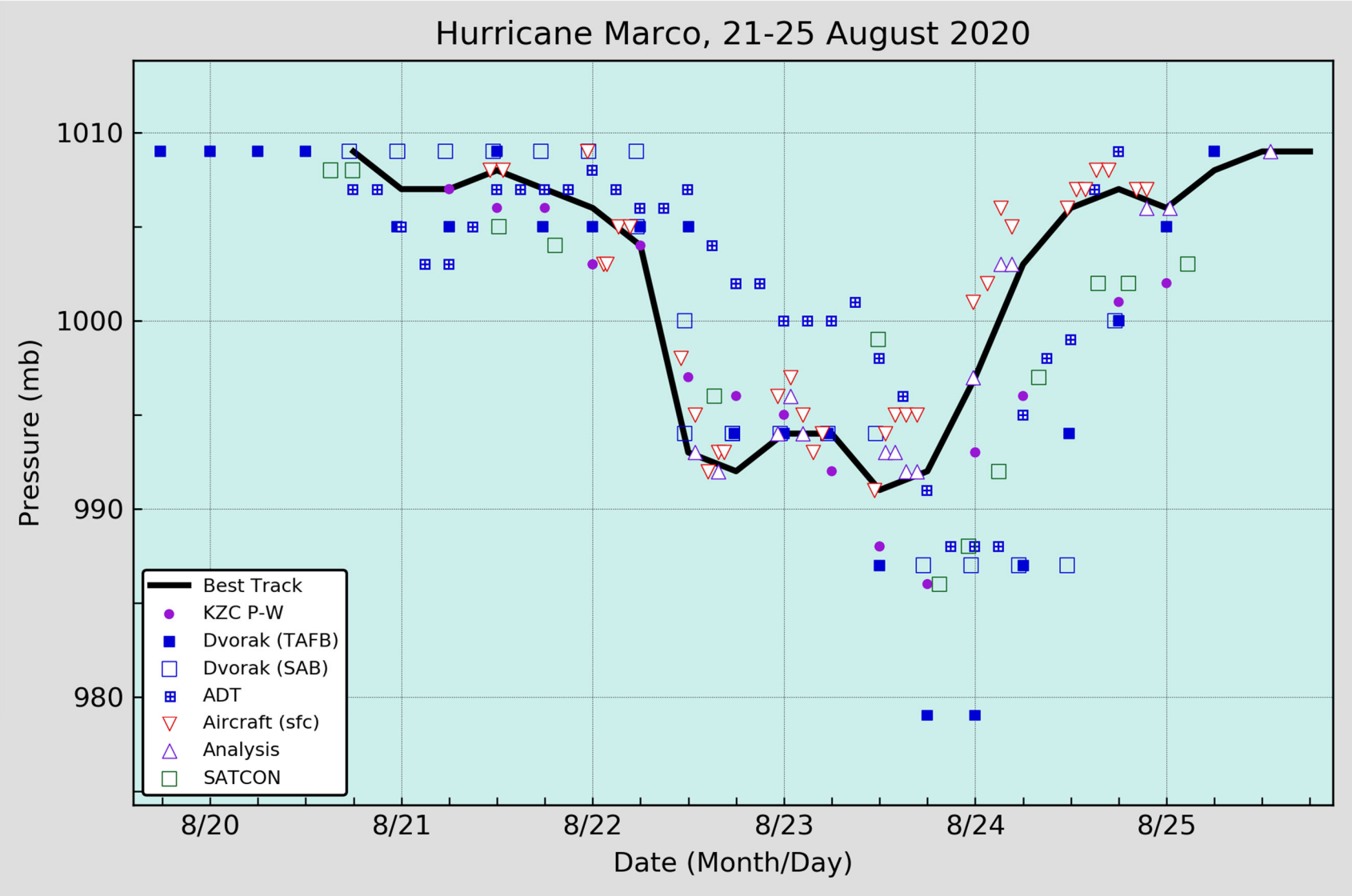

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Marco, 21–25 August 2020. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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.

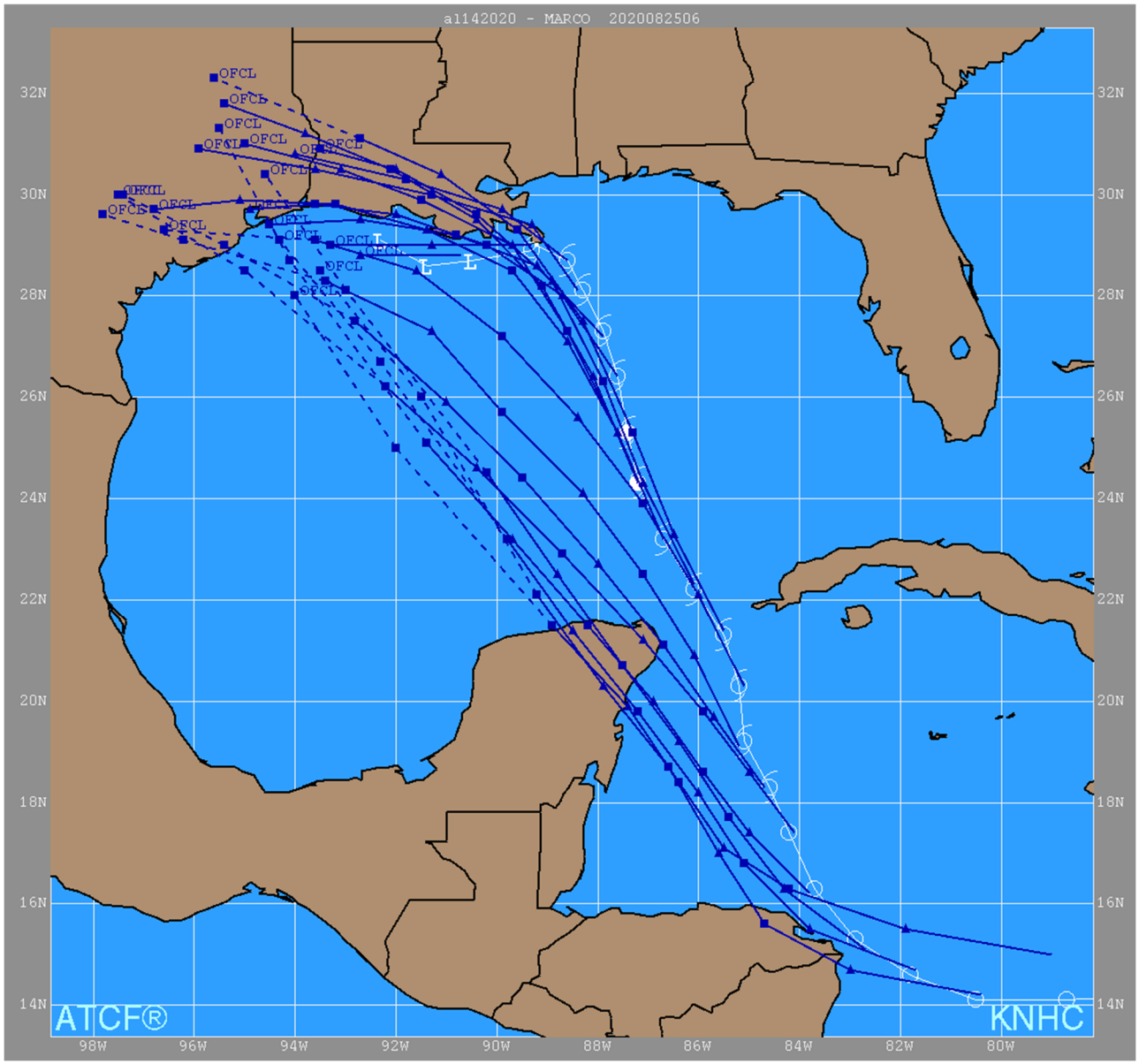

Figure 4. Selected official track forecasts (blue lines, with 0, 12, 24, 36, 48, 72, 96, and 120 h positions indicated) for Hurricane Marco, 21–25 August 2020. The best track is given by the white solid line with positions given at 6 h intervals.

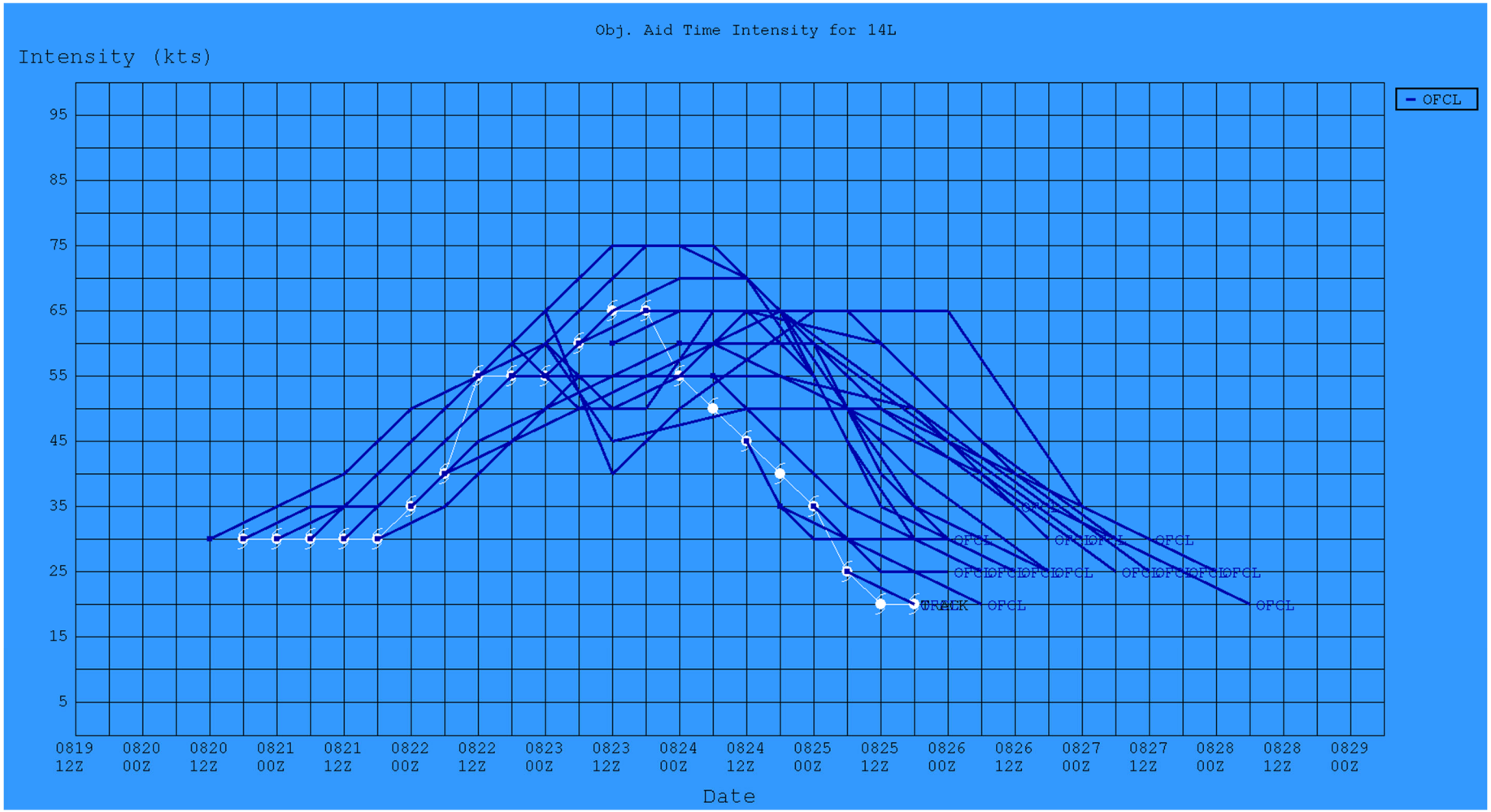

Figure 5. Selected official intensity forecasts (blue lines) for Hurricane Marco, 21–25 August 2020. The best track is given by the white solid line with intensities given at 6 h intervals.

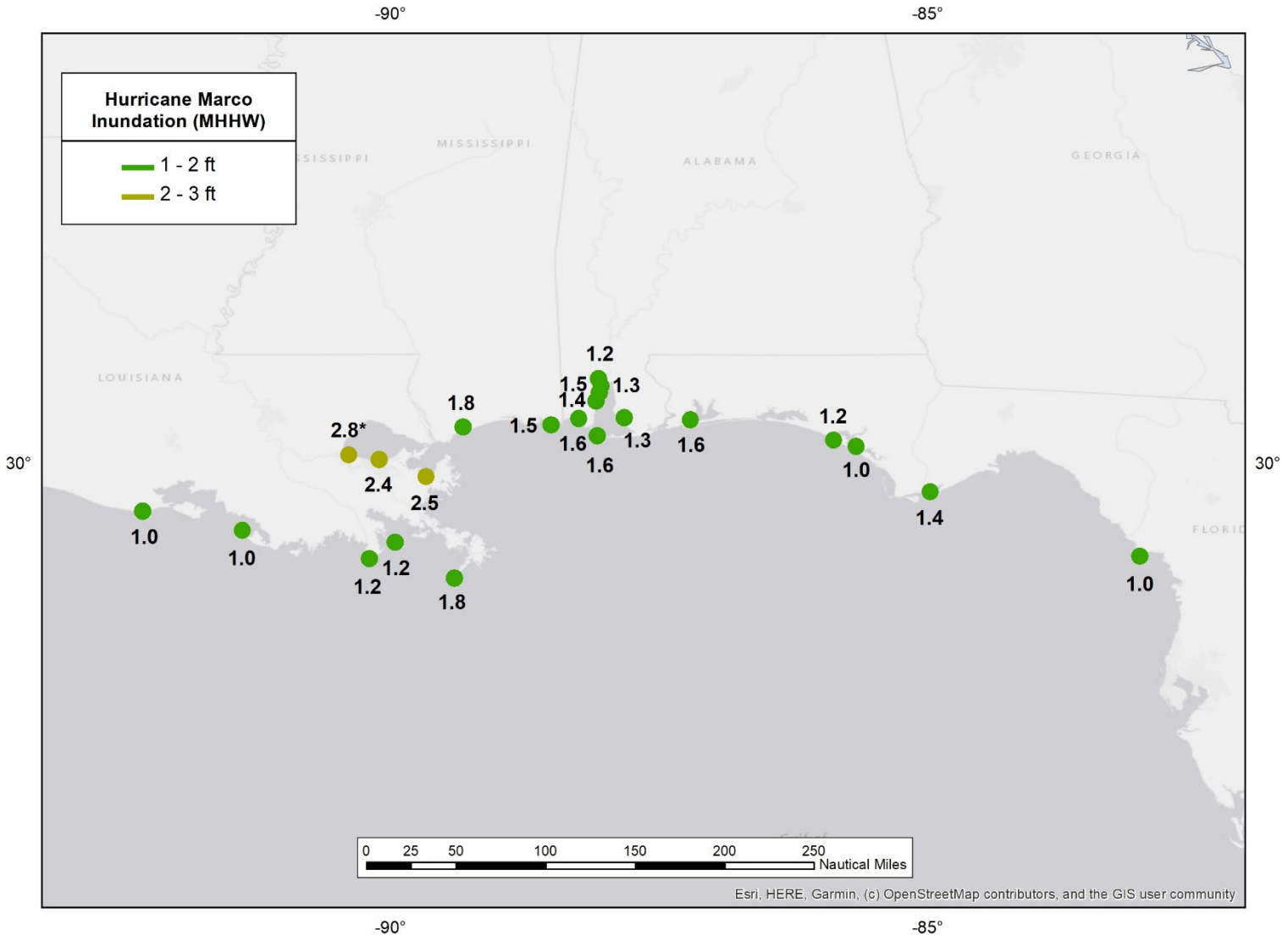

Figure 6. Maximum water levels measured from NOS tide gauges during Hurricane Marco, 21–25 August 2020. Water levels are referenced as feet above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline.

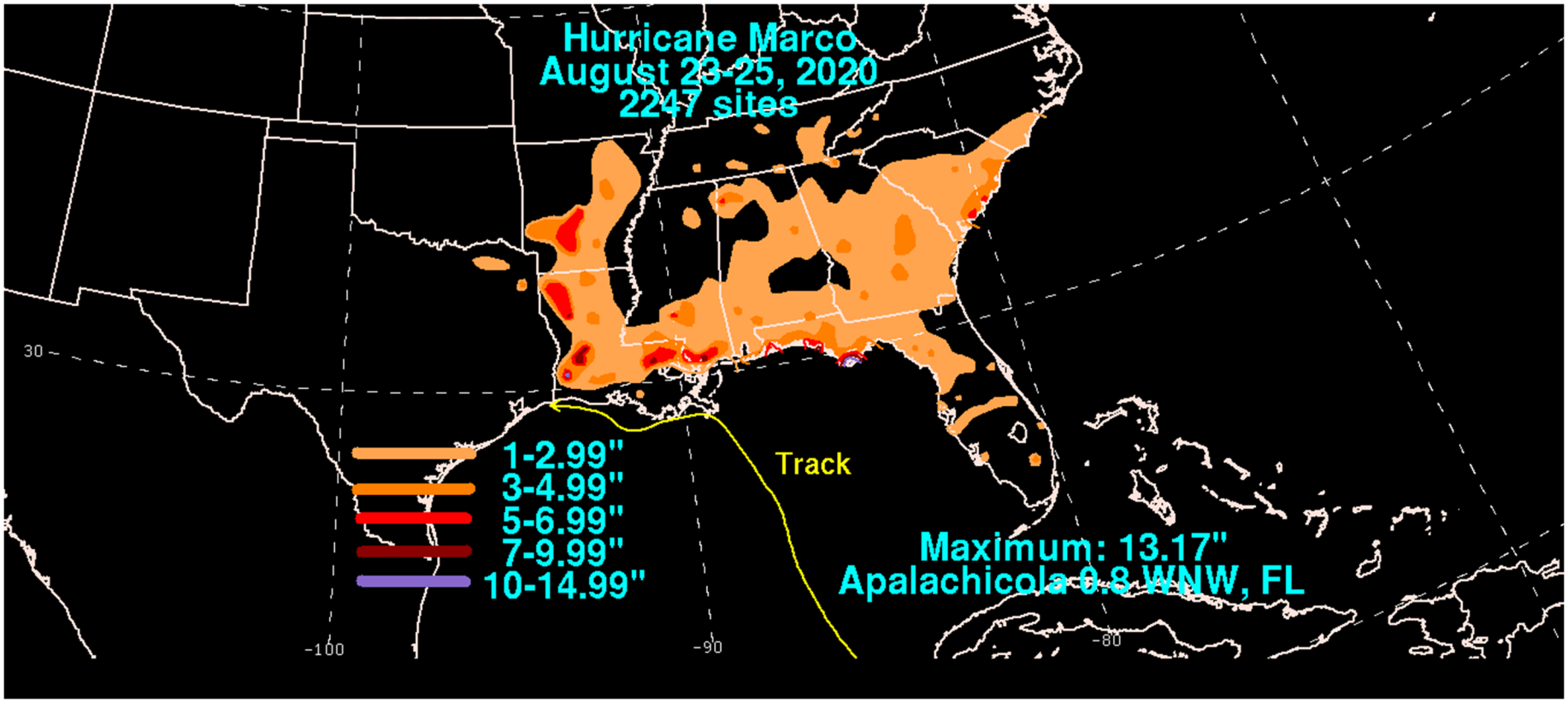

Figure 7. Storm total rainfall for Hurricane Marco, 21 – 25 August 2020. Data and imager courtesy of Dave Roth and Zack Taylor at the NOAA Weather Prediction Center, College Park, MD.

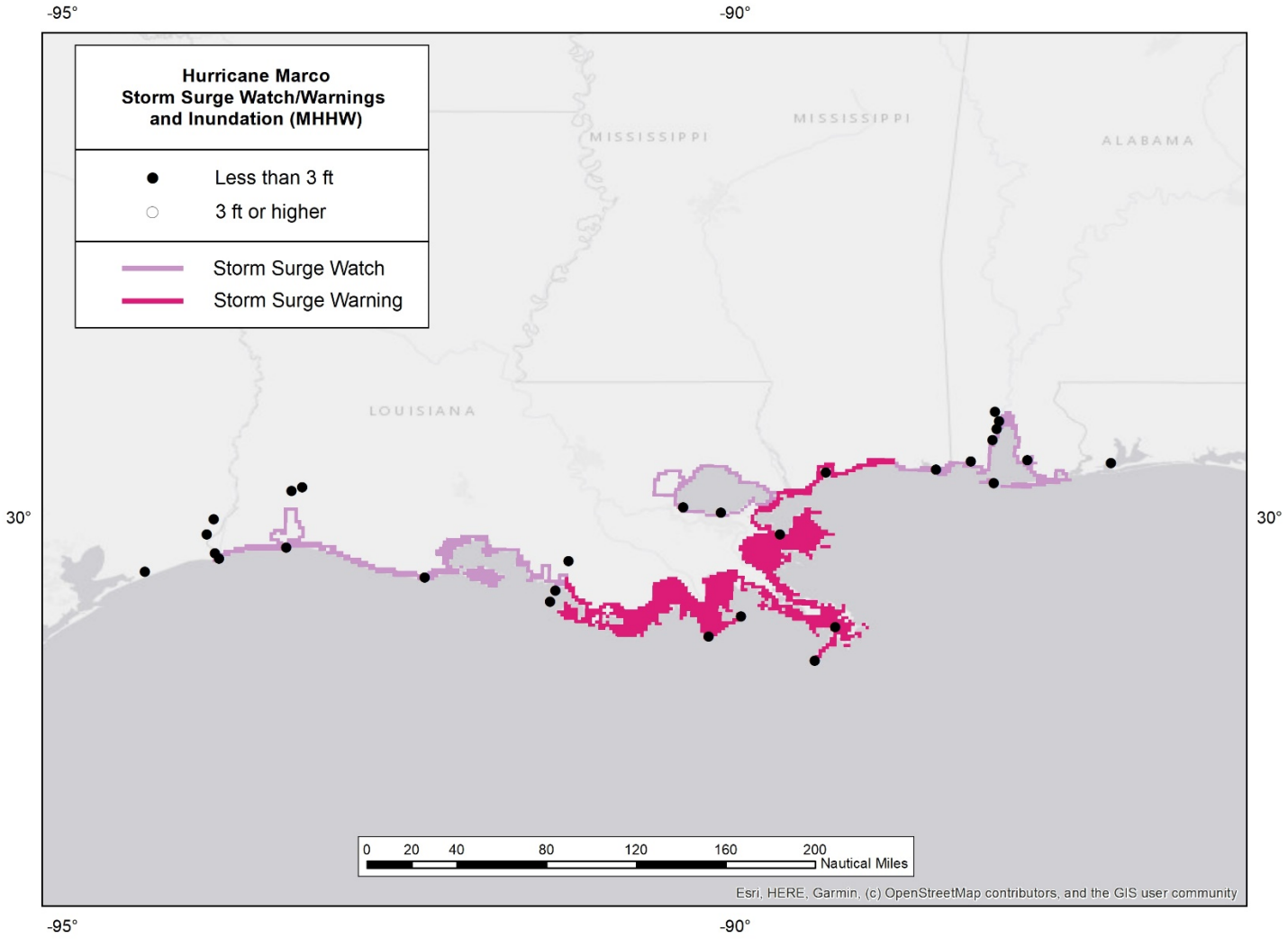

Figure 8. Maximum water levels measured during Hurricane Marco from tide gauges, and areas covered by storm surge watches (lavender) and warnings (magenta). Water levels are referenced as feet above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. Black markers denote water levels less than 3 ft above ground level, and white markers denote water levels 3 ft or higher above ground level.