NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE HANNA

(AL082020)

23–26 July 2020

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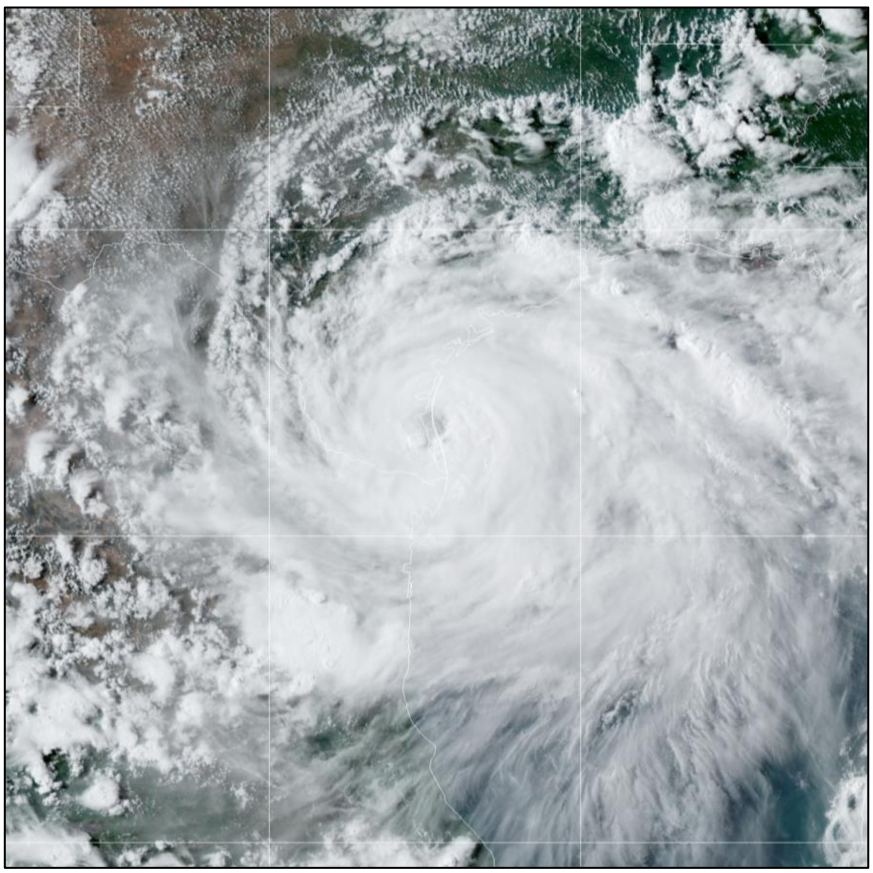

GOES-16 GEOCOLOR SATELLITE IMAGE OF HURRICANE HANNA AT 2230 UTC 25 JULY NEAR THE TIME OF BOTH PEAK INTENSITY AND LANDFALL ALONG THE COAST OF SOUTH TEXAS.

Hanna was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that made landfall on Padre Island, Texas. Hanna was the first July hurricane to make landfall in Texas since Hurricane Dolly in July 2008.

Hurricane Hanna

23–26 JULY 2020

SYNOPTIC HISTORY

Hanna developed from a tropical wave that appears to have departed the west coast of Africa late on 11 July. While the wave was initially accompanied by a large area of showers and thunderstorms when it moved offshore, dry mid-level air over the tropical Atlantic caused the thunderstorm activity to quickly dissipate. These dry conditions prevented development of the system over the next several days while it trekked westward. The wave was still mostly convection free when it approached the Lesser Antilles late on 17 July, but the northern portion of the wave became more convectively active the next day when it passed near the Virgin Islands and Puerto Rico. On 19 July, the forward speed of the wave slowed while deep convection continued to increase and spread across portions of the Greater Antilles and the southeastern and central Bahamas, but unfavorable upper-level winds prevented the system from becoming better organized. By late on 20 July, the wave axis extended from the central Bahamas to eastern Cuba, and it moved across central Cuba and southern Florida early the next day where it produced locally heavy rainfall. By the afternoon of 21 July, the wave reached the southeastern Gulf of Mexico, and a broad area of low pressure formed as upper-level winds became more conducive for development. The center of the low became well defined by late the next day, and the convection gained enough organization for the system to be classified as a tropical depression by 0000 UTC 23 July, when it was located over the central Gulf of Mexico about 210 n mi south-southeast of the mouth of the Mississippi River. Data from an Air Force Reserve reconnaissance aircraft indicated that the system had maximum winds of around 25 kt at the time of genesis. 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].

After formation, the depression moved slowly westward to west-northwestward south of a mid-level ridge axis. The system was located within an environment of light-to-moderate vertical wind shear and over an area of high upper-ocean heat content, but nearby mid-level dry air only allowed gradual strengthening during the following 24 h. The depression did not become a tropical storm until 0000 UTC 24 July when it was located about 200 n mi south-southwest of the mouth of the Mississippi River. Convective banding increased over the next 12 h, and Hanna began to strengthen at a slightly faster rate while it moved west-northwestward over the central Gulf of Mexico. By 1200 UTC 24 July, Hanna turned westward when a deep-layer ridge strengthened over the central United States.

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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.

Convection continued to gain organization while Hanna was located within low vertical wind shear conditions. Microwave imagery from 1944 UTC 24 July revealed a significantly improved inner-core structure with the development of a low- to mid-level eye feature (Fig. 4), and the cyclone strengthened into a 55-kt tropical storm by 0000 UTC 25 July. Hanna attained hurricane status 12 h later when it was located about 80 n mi east-northeast of Port Mansfield, Texas. Around that time, Hanna turned west-southwestward to the south of the aforementioned deep-layer ridge, and the hurricane remained on that heading for the remainder of its lifecycle. Doppler radar data along with NOAA and Air Force Reserve Hurricane Hunter aircraft data indicate that Hanna continued to intensify, reaching an estimated peak intensity of 80 kt by 1800 UTC 25 July when the center was located just off the coast of South Texas. Hanna continued to move west-southwestward at around 7 kt and made landfall around 2200 UTC 25 July on Padre Island, Texas (cover photo, Fig. 5), with an estimated intensity of 80 kt. After moving over the Laguna Madre, the eye of Hanna made a second landfall along the mainland coast of Texas also with an estimated intensity of 80 kt around 2315 UTC over eastern Kenedy County, about 10 n mi north-northwest of Port Mansfield.

After landfall, the hurricane began to quickly weaken while moving over far south Texas. Hanna weakened to a tropical storm by 0600 UTC 26 July, and continued its rapid decay as the center moved over northeastern Mexico. Hanna weakened to a tropical depression by 1800 UTC 26 July when it was located near Monterrey, Mexico. The low-level circulation dissipated shortly thereafter over the mountainous terrain of Mexico.

METEOROLOGICAL STATISTICS

Observations in Hanna (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 seven reconnaissance aircraft missions into Hanna, including three flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command, and four flights of the NOAA WD-P3 aircraft of the NOAA Aircraft Operations Center. A total of 17 center fixes were provided by reconnaissance aircraft during Hanna's lifecycle. 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 Hanna. NWS WSR-88D Doppler Radar data from Brownsville and Corpus Christi, Texas, were used to make center fixes and obtain velocity data while Hanna was near the U.S. coast.

Ship reports of winds of tropical storm force associated with Hanna are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3. Note that the wind observations from the ships *Pacific Sharav* (call sign D5DY4) and *Pacific Khamsin* (call sign D5DE5) on 24 July (Table 2) were from highly elevated anemometers, and support winds of around 40 kt after adjusting to a standard 10-m (surface) elevation.

Winds and Pressure

Hanna's estimated peak intensity of 80 kt from 1800 UTC 25 July through its final landfall at 2315 UTC 25 July along the mainland coast of Texas is based on data from an Air Force Reserve Hurricane Hunter aircraft. The aircraft measured a peak SFMR wind of 81 kt just after 1900 UTC and peak 700-mb flight-level winds of 86 kt at 2010 UTC. A dropsonde released in the southeastern eyewall of the hurricane at 1915 UTC measured a mean boundary layer (0–500 m) wind of 98 kt, which corresponds to an estimated surface wind of 79 kt. Another dropsonde released in the northeastern eyewall just before 2000 UTC measured a mean wind in the lowest 150 m of the sounding of 87 kt, which equates to a surface wind of around 72 kt. In addition to the aircraft data, peak average NWS Doppler radar velocities of around 100 kt at an elevation of 5000–6000 ft also support the estimated peak intensity of 80 kt.

The center of Hanna passed nearly directly over NOAA buoy 42020, located about 35 n mi east of Padre Island, Texas, on 25 July. The buoy reported a minimum pressure of 977.4 mb at 1730 UTC that day. A couple of hours later, the buoy measured a peak 1-minute wind of 68 kt[2] and a gust to 76 kt at 1930 UTC 25 July when it was located within the eastern eyewall of the hurricane. This is the highest sustained wind from any observing site in Hanna. The wind measurement from that buoy is at a height of 4.1 m, and adjusting this wind to a standard 10-m elevation yields a surface wind estimate of 75 kt. Although there were no reports of sustained winds of hurricane force along the coast of south Texas, primarily due to the sparse nature of observing sites along that section of coastline, a Texas Coastal Ocean Observing Network (TCOON) site near Rincon del San Jose measured peak sustained winds of 61 kt and a gust to 90 kt at 2006 UTC 25 July. Another TCOON observing site near Baffin Bay reported a peak sustained wind of 56 kt and a gust to 70 kt, but the observation record from that station is incomplete. Wind gusts of tropical storm force were reported along much of the Texas coast from near Galveston southward. A wind gust to 57 kt was reported at the Corpus Christi Naval Air Station, a gust to 55 kt was reported at Harlingen, and a gust to 52 kt was observed at McAllen International Airport. Although no reports of tropical-storm-force winds have been received from Mexico, it is likely that Hanna produced an area of tropical-storm-force winds in portions of northeastern Mexico on 25–26 July.

[2] The buoy reported a peak 1-minute wind of 68 kt in real time, but this observation is currently not available in the NOAA National Data Buoy Center (NDBC) web historical files. The observation is available in the official archive files at the NOAA National Centers for Environmental Information (NCEI). It has been determined that one of the anemometers on the buoy measured the 68-kt peak 1-minute wind speed while a slightly lower value from a second anemometer on the buoy was reported in the web historical files. According to NDBC, both are valid, and the higher value is referenced in this report.

Hanna's estimated minimum pressure of 973 mb at landfall on Padre Island is based on dropsonde data from an Air Force Reserve Hurricane Hunter aircraft. A dropsonde released in Hanna's eye just after 1900 UTC 25 July measured a minimum pressure of 974 mb and a surface wind of 11 kt, which supports the 973 mb minimum pressure. The lowest pressure measured along the Texas coast was at the Rincon del San Jose TCOON site, which reported a minimum pressure of 976.1 mb at 2254 UTC 25 July. This observation is the basis for the 974 mb pressure estimated at Hanna's second landfall on the coast of mainland Texas.

Storm Surge[3]

The highest measured storm surge from Hanna was 6.24 ft above normal tide levels at a NOAA National Ocean Service (NOS) gauge at Bob Hall Pier in Corpus Christi, Texas. The combination of this surge and the tide produced inundation levels of 3 to 5 ft above ground level along portions of the Middle and Lower Texas coast, including within Corpus Christi Bay, Nueces Bay, and Aransas Bay. Table 3 and Figure 6 provide maximum water levels measured from NOS and TCOON tide gauges referenced as feet above Mean Higher High Water (MHHW)[4], which is used as a proxy for inundation on normally dry ground along the immediate coastline. The Bob Hall Pier gauge, on the exposed coast of the Gulf of Mexico, measured a peak water level of 5.4 ft MHHW. Within Nueces Bay, a TCOON gauge recorded a peak water level of 4.4 ft MHHW, while a gauge at the USS Lexington in Corpus Christi Bay measured a peak water level of 3.8 ft MHHW.

The peak water level measured by the Bob Hall Pier tide gauge was corroborated by a nearby high-water mark of 4.5 ft above ground level surveyed by a crew from the Harris County Flood Control District and the National Weather Service. This was the highest stillwater high water mark surveyed by the crew. The crew also surveyed high water marks as high as 10 ft above ground level, but these debris lines and marks included the effect of waves and are not representative of stillwater inundation. Table 3 provides stillwater high water marks surveyed by the Harris County Flood Control District and National Weather Service crew.

Moderate to minor coastal flooding of 1 to 3 ft above ground level occurred elsewhere along the Texas coast. A peak water level of 3.6 ft MHHW was measured by a TCOON gauge at Port Lavaca on Matagorda Bay, and a TCOON gauge at Rincon del San Jose within Laguna

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[3] 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).

[4] Several gauges along the Lower Texas coast are located within non-tidal parts of Laguna Madre, and their data are referenced above Mean Sea Level (MSL).

Madre recorded a peak water level of 3.4 ft MSL. Along the Upper Texas coast, the highest measured water level was 2.9 ft MHHW at San Luis Pass.

Winds on the northern side of Hanna during its formative stages also produced minor coastal flooding of generally 1 to 2 ft above ground level along the coasts of Louisiana, Mississippi, Alabama, and the Florida Panhandle. The peak water levels recorded by NOS tide gauges in each state were 2.7 ft MHHW at Freshwater Canal Locks, Louisiana; 2.2 ft MHHW at Bay Waveland Yacht Club, Mississippi; 2.2 ft MHHW at Coast Guard Sector Mobile, Alabama; and 1.7 ft MHHW at Panama City Beach, Florida.

Rainfall and Flooding

In the United States, the heaviest rainfall produced by Hanna fell primarily across southern Texas and the Rio Grande Valley, where storm total accumulations of 6 to 12 inches occurred (Fig. 7). Isolated storm total amounts of 12 to 15 inches occurred within that area in the Rio Grande Valley. The highest storm total of 15.49 inches fell near Santa Rosa, Texas, in western Cameron County. A rainfall total of 14.80 inches was recorded near Port Mansfield, 13.92 inches fell near La Joya, 12.50 inches was measured in McAllen, and 12.37 inches was observed near Harlingen (Table 3). A larger area of 3 to 6 inches of rainfall occurred to the north of the swath of heaviest rainfall, and 1 to 3 inches of rain were reported along coastal portions of Texas from the Houston/Galveston area southward.

Hanna also brought heavy rainfall and significant flooding to portions of northeastern Mexico. Data provided by Mexico's Comissión Nacional del Agua (CONAGUA) shows that the heaviest rainfall occurred in the northeastern portion of the country over the states of Nuevo León and Tamaulipas (Table 4, Fig. 8). A swath of 6 to 12 inches (approximately 150–300 mm) of rain fell along the path of Hanna with isolated totals of 12 to 18 inches (approximately 300–450 mm). The highest amounts occurred in and around the city of Monterrey where as much as 21.91 inches (556.5 mm) was recorded. Other sites near that city measured 14 to 17 inches (355 to 435 mm) of rain (Table 4).

Moisture associated with Hanna's precursor disturbance brought 3 to 6 inches of rainfall to portions of southern Florida and the Florida Keys during 21–24 July, with a maximum of 7.44 inches in Key West. A rainfall total of 6.11 inches was reported near Homestead, and 4.18 inches fell on Key Largo.

Tornadoes

Five EF-0 tornadoes were reported in association with Hanna across southern Texas. The first tornado occurred near Bonnie View during the afternoon of 25 July. The remaining tornadoes occurred during the evening and overnight hours of 25–26 July near the towns of Lagarto, Pernitas Point, Sutherland Springs, and Brownsville. The tornadoes generally downed trees and produced minor structural damage. The most significant damage was reported with the tornado that occurred near Brownsville when it struck the west side of the Brownsville airport. A dozen windows were blown out at an airport hangar, and the tornado moved a Boeing 737 aircraft, which damaged a hangar wall. The tornado also snapped several large tree limbs and damaged the roof of two homes in a neighborhood adjacent to the airport. There were no injuries reported in association with the tornadoes.

CASUALTY AND DAMAGE STATISTICS

Hanna was responsible for at least four direct fatalities[5] in Mexico, all related to heavy rainfall and inland flooding. Media reports indicate that several other people were reported missing. There were no direct deaths in association with Hanna in the United States, but the storm caused five indirect fatalities in Texas. Hanna is estimated to have caused $1.2 billion (USD) in damage in the United States and Mexico combined.

United States

Hanna caused a total of 5 indirect deaths in the United States, all in the state of Texas, with four of these occurring due to carbon monoxide poisoning in Edinburg. The other indirect death occurred in Alton when a person fell off of a ladder while clearing storm debris. Before Hanna became a tropical cyclone, rough surf associated with the precursor disturbance contributed to the drowning of a 33-year-old man in Walton County, Florida, on 22 July after he rescued his 10-year-old son.

The NOAA National Centers for Environmental Information (NCEI) estimates that Hanna caused over $1.1 billion (USD) in damage in the United States, primarily to coastal infrastructure and agriculture, including extensive damage to cotton, citrus, sugarcane, and vegetable crops across the Rio Grande Valley in southern Texas. Hundreds of trees were snapped or uprooted by strong winds, and significant damage to utility poles caused widespread power outages across southern Texas, including 150,000 residences in Hidalgo County and 50,000 residences in Cameron County. Several mobile homes were destroyed, and hundreds of poorly built structures suffered roof damage. A couple of tractor trailers overturned on I-69E/US 77 in the eyewall during landfall in Kenedy County, which resulted in the road's closure.

Heavy rainfall produced flash flooding that required numerous water rescues in Hidalgo and Cameron Counties. The combination of heavy rain and poor drainage in some locations resulted in areal flooding and secondary road closures that lasted several days after landfall. Dozens of low-lying buildings were flooded with up to a couple feet of water. In Nueces

[5] 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.

County, Hanna's storm surge caused significant beach erosion, flooded numerous roads, and damaged some public facilities. Storm surge entered several buildings, including the Art Museum of South Texas and the Texas State Aquarium in Corpus Christi. The combination of storm surge and powerful wave action from Hanna severely damaged the Bob Hall Pier on Padre Island. Three people were rescued from a sinking sailboat at Marina Del Sol in Corpus Christi.

Mexico

In Mexico, media reports indicate that there were at least four direct fatalities due to Hanna with several other people reported missing. A 35-year-old mother and her 7-year-old daughter drowned in Ramos Arizpe when their vehicle was swept away by floodwaters. Two other children were reportedly in the vehicle; one child was later found alive, and one was still missing. Two people died in Reynosa, including a woman who suffered a seizure and drowned in floodwaters. Three people were reported missing in Reynosa after they were swept away by floodwaters, and three others were reported missing in Monterrey.

Media reports also indicated that the worst damage from Hanna's torrential rainfall occurred in the Mexican states of Coahuila, Nuevo León, and Tamaulipas. There were at least ten water rescues performed in Nuevo León and eight rescues in Coahuila. Over 250 houses were flooded in Coahuila, and more than 45 neighborhoods were damaged in Reynosa with around 200 people displaced by floodwaters. A maternity hospital in Reynosa was flooded, which required some patients to be moved to higher floors or evacuated to other hospitals. In Monterrey, floodwaters blocked overpasses and forced over 40 road closures within the city. Numerous cars were stranded on flooded roadways, and dozens of water rescues occurred. The main highway linking Monterrey and Reynosa was also closed due to flooding. Additionally, strong winds damaged trees, billboards, and elevated signs in Monterrey. It is estimated that Hanna damaged thousands of structures in Mexico.

According to the August 2020 Global Catastrophe Recap from Aon, Hanna produced an estimated $100 million (USD) in economic losses in Mexico.

FORECAST AND WARNING CRITIQUE

Genesis

The genesis of Hanna was not well anticipated. The tropical wave from which Hanna formed was introduced in the Tropical Weather Outlook (TWO) with a low chance (<40%) of development over the next 5 days about 90 h prior to genesis when the system was located near eastern Hispaniola (Table 5). The 5-day genesis potential was raised to the medium category (40–60%) 36 h before formation, and it did not reach the high category (>60%) until 6 h before Hanna formed. The short-range (0–48 h) genesis probabilities also did not provide as much lead time as usual. Although the first short-range chance of formation was mentioned in the Outlook

60 h before development, the 48-h probably of formation was not raised to the medium and high categories until 12 and 6 h before genesis occurred, respectively. The initial NHC genesis forecasts were correct in indicating that the wave would not have a chance to develop until it reached the Gulf of Mexico; however, the lack of lead time for the medium and high chances of formation were the result of poor global model forecasts within 3 to 4 days of Hanna's development. GFS model runs in the days leading up to Hanna's genesis only occasionally indicated that a weak area of low pressure might form before the system moved into Texas, but none of those model runs significantly deepened the system. The ECMWF and UKMET deterministic models also showed a lack of development, and only about 5 to 10% of the ECMWF ensemble members 3 to 4 days before formation suggested that a low could form over the western Gulf of Mexico.

Track

A verification of NHC official track forecasts for Hanna is given in Table 6a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period through 60 h, and slightly above the 5-year mean at 72 h. Due to Hanna's short life span there were no verifying 4- or 5-day forecasts. A homogeneous comparison of the official track errors with selected guidance models is given in Table 6b. The NHC track forecast errors were comparable to or slightly better than nearly all of the various track aids through 48 h. The ECMWF (EMXI) was the best performing model at 60 and 72 h, albeit for a small sample size. Several of the consensus aids also had slightly lower mean track errors than the official forecast at 48–72 h. The NHC track forecasts (Fig. 9) and most of the track aids suffered from a poleward bias in predicting Hanna's track, especially during the first 24 h of the tropical cyclone's existence. This was likely the result of the models not deepening Hanna much as what occurred. A weaker and more vertically shallow cyclone would have been steered westward to west-northwestward within the easterly to southeasterly low-level flow. After Hanna became a stronger and more vertically deep cyclone, it turned westward to west-southwestward within the deep-layer east-northeasterly flow. This resulted in Hanna making landfall farther south along the Texas coast than indicated in the first few NHC forecasts.

Intensity

A verification of NHC official intensity forecasts for Hanna is given in Table 7a. Official forecast intensity errors were comparable to the mean official errors for the previous 5-yr period at 12 and 24 h, but well above the long-term mean from 36 to 72 h. The 48- and 60-h mean official intensity errors were nearly double the long-term means. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 7b. The NHC intensity forecast outperformed most of the intensity aids, except for the HFIP corrected-consensus model (HCCA) at 12 through 48 h. The NHC intensity forecasts and nearly all of the guidance models under-predicted Hanna's intensity (Fig. 10). Because of the large and sprawling structure of the system when it first formed, nearby mid-level dry air, and the fairly short duration (less than 72 h) that the system was forecast to remain over the waters of the Gulf of Mexico, only gradual strengthening was indicated by the intensity aids and global model guidance. Therefore, the first NHC intensity forecast only called for Hanna to reach a peak intensity of 40 kt. Subsequent forecasts issued on 23 July predicted slightly higher peak intensities, but it was not until 2100

UTC 24 July, a little more than 24 h before Hanna made landfall in Texas, that the NHC intensity forecast explicitly called for Hanna to become a hurricane.

Storm Surge Forecasts and Warnings

Storm surge warnings associated with Hanna are given in Table 8. A Storm Surge Warning was first issued for a portion of the Texas coast from Baffin Bay to Sargent, including Corpus Christi Bay, Copano Bay, Aransas Bay, San Antonio Bay, and Matagorda Bay at 2100 UTC 24 July, a little less than 24 h before sustained tropical-storm-force winds reached the coast. The warning area was extended south of Baffin Bay to Port Mansfield, Texas, at 0900 UTC 25 July. 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) occurred within the Storm Surge Warning area (Fig. 11). A couple of tide stations outside of the Storm Surge Warning area reported peak water levels a little above 3 ft MHHW, although at least one of them (Nueces Bay) may include freshwater contribution from the Nueces River.

Because Hanna was not expected to reach hurricane intensity in the first set of forecasts, the chance for storm surge inundation of 3 ft or greater was initially low, and storm surge watches were therefore not issued during the 24–48 h period before sustained tropical-storm-force winds reached the coast. The risk of storm surge inundation of 3 ft or greater increased to criteria within the warning period, thus storm surge warnings were issued on the afternoon of 24 July without prior storm surge watches (Table 8).

The first forecast for peak storm surge inundation was 1 to 3 ft above ground level between the mouth of the Rio Grande and High Island, Texas, including Corpus Christi Bay, Matagorda Bay, and Galveston Bay, issued at 1500 UTC 24 July. The forecast was increased to 2 to 4 ft above ground level from Baffin Bay to Sargent later that afternoon (2100 UTC) with the issuance of the Storm Surge Warning and then to 3 to 5 ft that evening (0300 UTC 25 July). The forecast range was further increased to 4 to 6 ft the next afternoon (1800 UTC) just before landfall. Coastal observations indicate that peak water levels fell within the forecast range and were as high as about 5 ft above ground level along portions of the Middle and Lower Texas coast.

Wind Watches and Warnings

Coastal wind watches and warnings associated with Hanna are given in Table 9. A Tropical Storm Watch was issued for the Texas coast from Port Mansfield to High Island with the initial NHC advisory at 0300 UTC 23 July. At the time, the NHC forecast called for Hanna to make landfall as a tropical storm near Port O'Connor, Texas. Most of the watch area was upgraded to a Tropical Storm Warning at 2100 UTC 23 July. As the NHC forecast track shifted southward, the Tropical Storm Warning area was extended southward to the Mexico border at 0300 UTC 24 July, and eventually southward along portions of coast of northeastern Mexico. As the NHC intensity forecast was raised and the threat of Hanna becoming a hurricane increased, a Hurricane Warning was issued for a portion of the Texas coast at 2100 UTC 24 July (Table 9). The Hurricane Warning was issued a little less than 24 h before sustained tropical-storm-force winds reached the coast. The initial Tropical Storm Warning was issued about 42 h before tropical-storm-force winds are estimated to have begun along the Texas coast.

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

The NHC was in communication with emergency managers in the days leading up to and through Hanna's landfall in Texas on 25 July. This communication included calls, briefings, and federal video-teleconferences with FEMA Headquarters, FEMA Region 6, and the State of Texas. These decision support briefings were coordinated through the FEMA Hurricane Liaison Team, embedded at the NHC. In addition, the NHC director maintained direct communications with senior state emergency management officials in Texas to discuss the evolving threat. NHC's Tropical Analysis and Forecast Branch provided five briefings to officials at United States Coast Guard District 8. Although the NHC media pool was not activated, NHC conducted media interviews via phone and provided Key Messages and other hazard and warning information via Facebook and Twitter.

ACKNOWLEDGEMENTS

Data in Table 3 were compiled from Post Tropical Cyclone (PSH) Reports issued by the NWS Weather Forecast Offices (WFOs) in Houston, Corpus Christi, and Brownsville, Texas. Additional data were used from reports sent by the National Data Buoy Center and the NOS Center for Oceanographic Products and Services. Roger Edwards of the NOAA Storm Prediction Center also provided information on tornadoes, and David Roth of the NOAA Weather Prediction Center provided rainfall reports and analysis. Laura Alaka and William Booth of the NHC Storm Surge Unit provided storm surge data, and Stacy Stewart assisted with radar and surface data analysis. Rainfall data from Mexico in Table 4 and Figure 8 was provided by Mexico's Comissión Nacional del Agua (CONAGUA).

Table 1. Best track for Hurricane Hanna, 23–26 July 2020.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
23 / 0000	25.7	88.3	1009	25	tropical depression
23 / 0600	25.8	89.0	1009	25	"
23 / 1200	25.9	89.7	1009	30	"
23 / 1800	26.0	90.4	1006	30	"
24 / 0000	26.2	91.1	1002	35	tropical storm
24 / 0600	26.6	92.0	1001	40	"
24 / 1200	27.1	92.8	1000	45	"
24 / 1800	27.2	93.7	997	50	"
25 / 0000	27.1	94.5	993	55	"
25 / 0600	27.1	95.3	988	60	"
25 / 1200	27.1	96.0	981	70	hurricane
25 / 1800	26.9	96.8	973	80	"
25 / 2200	26.8	97.3	973	80	"
25 / 2315	26.7	97.5	974	80	"
26 / 0000	26.7	97.6	976	75	"
26 / 0600	26.5	98.5	987	55	tropical storm
26 / 1200	26.2	99.3	996	40	"
26 / 1800	25.8	100.3	1000	30	tropical depression
27 / 0000					dissipated
25 / 1800	26.9	96.8	973	80	maximum wind and minimum pressure
25 / 2200	26.8	97.3	973	80	landfall on Padre Island, Texas
25 / 2315	26.7	97.5	974	80	landfall about 10 n mi north-northwest of Port Mansfield, Texas

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Hanna, 23–26 July 2020.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
24 / 1200	D5DY4	26.9	92.2	170 / 48	1005.0
24 / 1300	WWAA	27.4	92.0	130 / 35	1012.1
24 / 1400	D5DE5	26.9	92.2	170 / 51	1009.0
25 / 1500	WLIU	26.1	96.0	260 / 37	1001.9
25 / 1600	WDBH	28.3	95.2	150 / 55	1007.3
25 / 1800	WLIU	26.1	96.7	240 / 37	999.6
26 / 0600	WLIU	26.1	96.9	140 / 35	1006.1
26 / 0900	WLIU	26.5	96.9	140 / 35	1007.0

Table 3. Selected surface observations for Hurricane Hanna, 23–26 July 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)				
Offshore									
Buoys									
NOAA Buoy 42001 (25.94N 89.66W)	23/1010	1008.6	23/2138	27 (4 m. 1 min)	31				
42395 Shell Alcyone Buoy (26.40N 90.79W)	24/0020	1005.9	24/0832	33 (10 m)	45				
NOAA Buoy 42002 (26.06N 93.65W)	24/2130	1006.0	24/1955	35 (4 m. 1 min)	41				
NOAA Buoy 42019 (26.91N 95.35W)	25/0700	999.9	25/1145	50 (3 m, 1 min)	58				
NOAA Buoy 42020 (26.97N 96.69W)	25/1730	977.4	25/1930	68 (4 m, 1 min)	76				
TABS Buoy 42045 (25.94N 89.66W)	25/2100	998.8	25/1530	31 (4 m)	41				
Oil Platforms									
Green Canyon 787 (KATP) (27.20N 90.03W)	23/2200	1008.5	24/0400	32 (230 m)	38				
Garden Banks 668 (KGUL) (27.30N 93.53W)	24/1735	1000.3	24/2335	41 (68m)	48				
High Island 376 (KHQI) (27.97N 93.67W)	25/0935	1007.1	25/0255	46	50				
East Breaks 165 (KEMK) (27.82N 94.32W)	24/1955	1002.0	24/2055	55 (120m)	65				
Alaminos Canyon 25 (KHHV) (26.94N 94.69W)	25/0115	994.9	25/1215	43	66				
Brazos 133B Platform (KBBF) (28.06N 95.87W)	25/0945	997.9[i]	25/0655	51[i] (27.7 m)	66[i]				

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)				
Texas									
International Civil Aviation Organization (ICAO) Sites									
Galveston (KGLS) (29.27N 94.87W)	26/0152	1011.6	25/2157	20 (10 m, 2 min)	35				1.75
Angleton/Brazoria County Airport (KLBX) (29.12N 95.47W)	25/0853	1008.3	25/1453	26 (10 m, 2 min)	35				1.25
Beeville Municipal Airport (KBEA) (28.36N 97.79W)	26/0055	1006.4	26/0616	27 (10 m, 2 min)	39				0.82
Aransas County AP (KRKP) (28.09N 97.04W)	25/1953	1005.0	25/1737	32 (10 m, 2 min)	42				
Mustang Beach Airport (KRAS) (27.81N 97.09W)	25/2015	1002.7	25/1655	33 (10 m, 2 min)	45				
Nueces County Airport (KRBO) (27.78N 97.69W)	26/0015	1003.0	26/0215	27 (10 m, 2 min)	41				0.25
Corpus Christi Intl Airport (KCRP) (27.77N 97.50W)	25/2051	1002.4	25/1941	36 (10 m, 2 min)	47				3.53
Alice International Airport (KALI) (27.74N 98.03W)	26/0400	1005.0	26/0400	31 (10 m, 2 min)	41				2.74
Corpus Christi Naval Air Station (KNGP) (27.69N 97.29W)	25/1856	1001.1	26/0137	44 (10 m, 2 min)	57				3.08
Kingsville Naval Air Station (KNQI) (27.51N 97.81W)	26/0056	1000.3	25/2005	29 (10 m, 2 min)	46				
Hebbronville Jim Hogg Airport (KHBV) (27.35N 98.74W)	26/0555	1002.5	26/1055	28 (10 m, 2 min)	38				1.18
Falfurrias (KBKS) (27.21N 98.12W)	26/0115	997.9[i]	26/0015	30[i] (10 m, 2 min)	46[i]				3.21
Zapata County Airport (KAPY) (26.97N 99.25W)	26/0555	1002.5	26/1315	28 (10 m, 2 min)	36				4.38

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)				
Edinburg Intl Airport (KEBG) (26.44N 98.13W)	26/0035	992.8[i]	26/0035	39[i] (10 m, 2 min)	47[i]				
Harlingen (KHRL) (26.23N 97.66W)	26/0052	992.0[i]	26/0023	38[i] (10 m, 2 min)	55[i]				
Weslaco - Mid Valley Airport (KTXW) (26.18N 97.97W)	26/0235	993.8	26/0215	37 (10 m, 2 min)	51				6.53
McAllen Intl Airport (KMFE) (26.18N 98.24W)	26/0428	993.2	26/0845	34 (10 m, 2 min)	52				8.30
Port Isabel (KPIL) (26.16N 97.34W)	26/0004	995.9	26/0852	40 (10 m, 2 min)	48				
Brownsville Intl Airport (KBRO) (25.91N 97.42W)	26.0331	999.7	26/1012	32 (10 m, 2 min)	42				4.32
Remote Automated Weather Stations (RAWS)									
Hebbronville (HVLT2) (27.35N 98.74W)			26/0146	24[i] (6.1m, 10 min)	42[i]				1.82
Laguna Atascosa (ATRT2) (26.23N 97.35W)			25/2322	23 (6.1m, 10 min)	48				
Falcon Lake (FART2) (26.55N 99.14W)			26/0611	23 (6.1m, 10 min)	45				9.84
Linn San Manuel (LSRT2) (26.54N 98.09W)			26/0046	24 (6.1m, 10 min)	53				6.78
Citizen Weather Observer Program (CWOP)									
Mission (FW6820) (26.25N 98.41W)	26/0225	993.9							
La Joya (DW1157) (26.25N 98.49W)	26/0544	987.2							
Mission (EW6141) (26.23N 98.30W)	26/0400	991.2							12.25
Mission (EW9532) (26.21N 98.30W)	26/0416	993.0							

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)				
La Feria (EW5801) (26.14N 97.82W)	26/0159	992.5							
Los Fresnos (CW8690) (26.12N 97.49W)	26/0036	995.0							
Laguna Vista (CW9478) (26.11N 97.31W)	25/2101	997.4							
Laguna Vista (DW1996) (26.10N 97.29W)	25/2300	996.4							
Los Fresnos (N5CEY) (26.09N 97.43W)	25/2315	999.2							
Brownsville (EW9626) (25.92N 97.52W)	25/2347	999.9							
Texas Water Development Board (TWDB)									
Rancho Los Comitas (TWB26) (26.77N 98.62W)	26/0555	992.7	26/0855	30 (3 m)	56				
Texas Agriscience (TWB67) (26.35N 97.90W)	26/0250	986.0	26/0420	47 (3 m)	69				10.98
Non-METAR									
Calosa (DT013) (27.05N 98.25W)			26/0215	20	36				
Armstrong Ranch (DT058) (26.92N 97.79W)			26/0245	35	56				
La Rucia (DT059) (26.83N 98.28W)			26/0530	23[i]	43[i]				
Texas Coastal Ocean Observation Network (TCOON), National Ocean Service (NOS), and Coastal-Marine Automated Network (C-MAN) Sites									
Rainbow Bridge (8770520) (29.98N 93.88W)						2.32	2.61	2.1	

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)				
Port Arthur (PORT2) (29.87N 93.93W)	25/0836	1010.9	25/1518	16 (11 m, 2 min)	25	2.31	2.60	2.0	
Sabine Pass North (SBPT2) (29.73N 93.87W)	25/0842	1012.4	24/1936	23 (8 m, 2 min)	29	2.76		2.3	
Texas Point (TXPT2) (29.69N 93.84W)	25/0900	1008.6	25/1236	35 (12.5 m, 2 min)	39	2,81	2.86	2.0	
Morgans Point (MGPT2) (29.68N 94.98W)	25/0924	1009.7	25/1718	22 (12.5 m, 2 min)	30	3.12	3.76	2.6	
High Island (HIST2) (29.59N 94.39W)	25/0848	1009.8	24/2024	24	29	2.67	2.80	2.1	
Rollover Pass (RLOT2) (29.52N 94.51W)	25/0924	1009.9	24/2218	27 (11 m, 2 min)	33	3.00	3.03	2.4	
Eagle Point (EPTT2) (29.49N 94.91W)	25/0930	1008.8	24/2342	26 (5.7 m, 2 min)	34	3.20		2.8	
Galveston North Jetty (GNJT2) (29.36N 94.72W)	25/0842	1008.1	24/2230	33 (12.1 m, 2 min)	44	2.98	3.33	2.2	
Galveston Pier 21 (GTOT2) (29.31N 94.79W)	25/0900	1008.5	24/2254	19 (5 m, 2 min)	30	3.26	3.60	2.5	
Galveston RR Bridge (GRRT2) (29.30N 94.90W)	25/0900	1008.3	25/1842	27 (10.7 m, 2 min)	35	3.20	3.49	2.6	
San Luis Pass (LUIT2) (29.08N 95.12W)	25/1018	1009.3	25/1106	30 (2 min)	44	3.49	3.74	2.9	
Freeport (FPST2) (28.94N 95.29W)	25/1006	1005.9	25/1200	35 (15 m, 2 min)	44	3.20	3.70	2.7	
Sargent (SGNT2) (28.77N 95.62W)	25/0936	1006.4	25/1600	31 (2 min)	44	2.68		2.3	
Manchester (NCHT2) (29.73N 95.27W)	25/0912	1009.2	24/1842	20	28	3.73	4.51	2.8	
East Matagorda (EMAT2) (28.71N 95.91W)	25/0936	1006.2	25/1112	28 (8.2 m, 2 min)	40	2.91	3.67	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)				
Port Lavaca (VCAT2) (28.64N 96.61W)	25/0954	1007.1[i]	26/0812	35 (10 m, 2 min)	50	3.85		3.6	
Port O'Connor (PCNT2) (28.45N 96.40W)	25/1048	1005.5[i]	25/1054	35 (9.1 m, 2 min)	43	3.26	4.16	3.1	
Matagorda Bay Entrance (MBET2) (28.42N 96.33W)	25/1024	1004.4	25/1442	38 (12 m, 2 min)	45	3.31	3.64	2.8	
Seadrift (SDRT2) (28.41N 96.71W)	25/0936	1006.5	26/0742	23 (10 m, 2 min)	33	2.64	3.91	2.6	
Aransas Wildlife Refuge (AWRT2) (28.23N 96.80W)	25/1536	1004.8	25/1548	34 (2 min)	42	2.69	3.83	2.6	
Rockport (RCPT2) (28.02N 97.05W)	25/1900	1003.2	25/1754	31 (6.1 m, 2 min)	45	2.82	3.81	2.5	
Port Aransas (RTAT2) (27.84N 97.07W)	25/1724	1002.4[i]	25/1800	39 (10.7 m, 2 min)	51	3.16	3.68	2.8	
Aransas Pass (ANPT2) (27.84N 97.04W)	25/1748	1000.6	25/1800	43 (14 m, 2 min)	63	3.96	4.07	3.3	
Port Aransas (PTAT2) (27.83N 97.05W)	25/1800	1001.2	25/1750	43 (15 m, 2 min)	54				
Nueces Bay (NUET2) (27.83N 97.49W)	25/2054	1003.1[i]	26/0536	39[i] (10 m, 2 min)	51[i]	4.63		4.44**	
USS Lexington (TAQT2) (27.81N 97.39W)	25/2142	1001.4				3.92	4.78	3.8	
Packery Channel (PACT2) (27.63N 97.24W)	25/1942	998.4	25/2012	44 (10.7 m, 2 min)	57	3.58	3.84	3.1	
Bob Hall Pier (MQTT2) (27.58N 97.21W)			26/0124	47[i] (13 m, 2 min)	62[i]	6.24	6.60	5.4	
South Bird Island (IRDT2) (27.48N 97.32W)	25/2012	997.6	25/1724	43 (4.3 m, 2 min)	55		2.47	1.9*	
Baffin Bay (BABT2) (27.30N 97.41W)	25/2142	992.4	25/2136	56[i] (10 m, 2 min)	70[i]		2.29	1.8*	

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Rincon Del San Jose (RSJT2) (26.80N 97.48W)	25/2254	976.1	25/2006	61 (10 m, 2 min)	90		3.86	3.4*	
Port Mansfield (PMNT2) (26.56N 97.42W)	25/2230	980.6[i]					2.98	2.7*	
Realitos Peninsula (RLIT2) (26.26N 97.29W)	25/2206	991.9[i]	25/2206	44[i]	55[i]	3.04		2.5	
South Padre Island CGS (PCGT2) (26.08N 97.18W)	25/2312	997.2	25/2118	38	46	2.31	2.14	1.7	
Brazos Santiago (BZST2) (26.07N 97.15W)	25/2254	996.8	26/0830	40 (14 m, 2 min)	53	2.38	1.95	1.7	
Port Isabel (PTIT2) (26.06N 97.21W)	25/2312	1000.1[i]	26/0942	33 (8.4 m, 2 min)	41	2.11	2.09	1.6	
Weatherflow Sites									
Levee (XLEV) (29.42N 94.89W)			25/2105	30 (8.2 m, 1 min)	34				
Surfside Beach (XSRF) (28.93N 95.29W)			25/0850	44 (7.6 m, 1 min)	51				
Matagorda Bay (XMGB) (28.59N 95.98W)			25/1040	38 (6.1 m, 1 min)	44				
Wildcat (XWLD) (27.87N 97.32W)			26/0456	42 (4.9 m. 1 min)	49				
Poenisch Park (XPOE) (27.72N 97.34W)			26/0115	41 (5.5 m, 1 min)	48				
Laguna Shores (XLAG) (27.64N 97.29W)			26/0107	50 (9.8 m, 1 min)	61				
Corpus Christi (XCRP) (27.60N 97.30W)			25/2221	47 (10 m, 1 min)	53				
SPIW Park (XSPP) (26.16N 97.18W)			25/2122	40 (5.5 m, 1 min)	48				
South Padre (XPAD) (26.08N 97.17W)			25/2119	43 (12.1 m, 1 min)	50				

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Harris County Flood Control District High Water Marks									
Corpus Christi – Bob Hall Pier (27.58N 97.22W)							9.40	4.5	
Corpus Christi (27.81N 97.39W)							5.80	3.4	
Port Lavaca – Lavaca Bay (28.64N 96.61W)							6.20	3.0	
Corpus Christi – North Beach (27.83N 97.39W)							5.50	2.5	
Corpus Christi – North Padre Island (27.63N 97.23W)							4.20	2.5	
Port Aransas – Mustang Island (27.68N 97.17W)							3.80	2.5	
Riviera – Radicha Creek (27.37N 97.75W)								2.5	
Point Comfort – Lavaca Bay (28.66N 96.58W)							4.90	2.0	
Weedhaven – Vaes Bay (28.72N 96.44W)							4.60	2.0	
Aransas Pass – Stedman Island (27.89N 97.13W)							3.64	2.0	
Port Alto – Carancahua Bay (28.66N 96.41W)							5.40	1.6	
Magnolia Beach – Matagorda Bay (28.56N 96.53W)							4.93	1.5	
Austwell – San Antonio Bay (28.39N 96.84W)							4.30	1.5	
Matagorda – Mouth of the Colorado River (28.60N 95.98W)							3.90	1.5	

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Seadrift – San Antonio Bay (28.41N 96.71W)							3.70	1.5	
Olivia – Keller Bay (28.64N 96.46W)							3.80	1.3	
Corpus Christi – North Beach (27.82N 97.39W)							5.50	1.2	
Rockport (28.05N 97.03W)							3.46	1.2	
Corpus Christi (27.72N 97.33W)							5.90	1.0	
Port O'Connor – Matagorda Bay (28.45N 96.41W)							4.75	1.0	
Weedhaven – Vaes Bay (28.73N 96.41W)							4.20	1.0	
Corpus Christi – JFK Causeway (27.64N 97.25W)							3.50	1.0	
Rockport (28.04N 97.04W)							3.18	1.0	
NWS Cooperative Observer Program (COOP) Sites									
Santa Rosa 3 WNW (SNRT2) (26.27N 97.87W)									15.49
Port Mansfield (PSFT2) (26.55N 97.43W)									14.80
Harlingen (HGNT2) (26.20N 97.67W)									11.72
McAllen 2 SW (MCAT2) (26.19N 98.25W)									8.23
Armstrong 4 SE (ARMT2) (26.84N 97.71W)									7.03
San Manuel (SMLT2) (26.57N 98.12W)									5.19

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Falfurrias 4 W (FAFT2) (27.23N 98.20W)									4.84
Sarita (SRTT2) (27.22N 97.70W)									4.77
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Port Mansfield 1.1 SE (TX-WC-8) (26.54N 97.42W)									14.76
Mission 3.5 NW (TX-HDL-55) (26.25N 98.36W)									14.40
La Joya 0.6 W (TX-HDL-14) (26.25N 98.49W)									13.92
McAllen 2.4 NE (TX-HDL-21) (26.24N 98.22W)									12.50
Harlingen 6.2 WSW (TX-CMR-100) (26.16N 97.78W)									12.37
McAllen 3.5 N (TX-HDL-50) (26.27N 98.24W)									12.03
Mission 1.9 ENE (TX-HDL-9) (26.22N 98.29W)									11.98
Harlingen 4.4 W (TX-CMR-93) (26.20N 97.76W)									11.61
Mission 9.6 N (TX-HDL-40) (26.35N 98.31W)									10.65
McAllen 1.7 SSE (TX-HDL-18) (26.19N 98.23W)									10.64
McAllen 2.7 NNE (TX-HDL-46) (26.25N 98.23W)									10.55
Edinburg 2.4 N (TX-HDL-41) (26.33N 98.17W)									9.78
Mission 4.3 WSW (TX-HDL-19) (26.19N 98.38W)									9.50

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Harlingen 0.4 N (TX-CMR-85) (26.20N 97.69W)									9.35
Mercedes 1.9 SW (TX-HDL-54) (26.13N 97.94W)									9.34
Rio Grande City 17.7 NE (TX-ST-2) (26.54N 98.60W)									9.30
Los Fresnos 2.1 NNE (TX-CMR-105) (26.10N 97.46W)									9.04
Harlingen 4.2 W (TX-CMR-121) (26.20N 97.75W)									8.82
San Benito 6.3 ENE (TX-CMR-96) (26.17N 97.54W)									8.74
Brownsville 12.6 E (TX-CMR-94) (25.95N 97.28W)									8.60
Harlingen 1.1 NE (TX-CMR-120) (26.20N 97.67W)									8.30
La Joya 11.1 N (TX-HDL-5) (26.41N 98.46W)									8.12
Los Fresnos 0.3 NE (TX-CMR-21) (26.08N 97.48W)									7.90
Brownsville 4 N (TX-CMR-16) (25.98N 97.49W)									7.49
Rio Grande City 3.5 ENE (TX-ST-8) (26.41N 98.78W)									7.30
Hebbronville 32.3 SSW(TX-JH-10) (26.90N 98.92W)									7.18
Brownsville 1.5 WNW (TX-CMR-90) (25.93N 97.51W)									7.13
Brownsville 2.2 W (TX-CMR-13) (25.92N 97.52W)									7.12

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)				
Laguna Vista 0.3 N (TX-CMR-58) (26.10N 97.29W)									6.47
Rancho Viejo 0.7 E (TX-CMR-1) (26.03N 97.55W)									6.41
Brownsville 2.8 N (TX-CMR-28) (25.97N 97.48W)									6.02
Hebbronville 21 SSE (TX-JH-8) (27.04N 98.53W)									5.85
Hebbronville 32 S (TX-JH-9) (26.85N 98.70W)									5.84
Brownsville 0.1 SSE (TX-CMR-51) (25.92N 97.48W)									5.53
Brownsville 6.4 SE (TX-CMR-8) (25.85N 97.42W)									5.30
Brownsville 7.0 NW (TX-CMR-31) (26.00N 97.57W)									5.28
Brownsville 0.4 WSW (TX-CMR-22) (25.92N 97.49W)									5.20
Brownsville 1.7 NNE (TX-CMR-89) (25.95N 97.47W)									5.08
Brownsville 2 ESE (TX-CMR-23) (25.92N 97.45W)									5.02
Brownsville 4 ENE (TX-CMR-43) (25.95N 97.43W)									5.00
San Ygnacio 2.3 SE (TX-ZP-2) (27.02N 99.41W)									4.96
Livingston 5.7 WSW (TX-PL-37) (30.68N 95.02W)									4.86
San Benito 0.9 SSE (TX-CMR-101) (26.12N 97.63W)									4.83

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	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[A]	Sustained (kt)[B]	Gust (kt)				
Laguna Vista 1.2 WNW (TX-CMR-124) (26.11N 97.31W)									4.72
Manvel 3.6 S (TX-BRZ-37) (29.43N 95.37W)									4.57
Falfurrias 8.9 SSW (TX-BRK-3) (27.11N 98.21W)									4.47
Premont 0.9 WSW (TX-JW-15) (27.35N 98.14W)									4.42
Hebbronville 22.1 SSW (TX-JH-7) (27.04N 98.87W)									4.41
Brownsville 6.4 WNW (TX-CMR-61) (25.96N 97.58W)									4.37
Hebbronville 15 SSE (TX-JH-12) (27.11N 98.61W)									4.27
Corpus Christi 4.8 W (TX-NU-38) (27.81N 97.47W)									4.18
Sandia 0.9 WNW (TX-JW-14) (28.03N 97.89W)									4.09
Other Sites									
Los Ebanos (RGLT2) (26.24N 98.56W)									14.59
La Joya (LJAT2) (26.25N 98.47W)									11.85
Santa Ana NWR (LWRT2) (26.08N 98.16W)									8.68
Sarita Fire Station (27.22N 97.79W)									6.20
Brownsville WFO (25.92N 97.42W)									4.57
Riviera (8209D) (27.28N 97.82W)									4.56

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)				
Roma 13 NW (BFAT2) (26.56N 99.17W)									4.37
Riviera 4 WSW (3417D) (27.27N 97.89W)									4.26
Riviera 5 WNW (9130D) (27.31N 97.91W)									4.00
Louisiana									
NOS Sites									
Freshwater Canal Locks (FRWL1) (29.55N 92.31W)	24/0930	1010.8	25/2000	19 (20 m)	29	3.00	3.59	2.7	
Shell Beach (SHBL1) (29.87N 89.67W)	23/2324	1013.1	24/0406	26 (16 m)	34	2.63	3.39	2.6	
I-10 Bonnet Carre Floodway (BCFL1) (30.07N 90.39W)						2.61	2.84	2.4**	
Eugene Island (EINL1) (29.37N 91.38W)	23/2306	1011.3	25/1800	28 (10 m)	35	2.29		2.3	
New Canal Station (NWCL1) (30.03N 90.11W)	23/2306	1012.1	23/1618	22 (12 m)	27	2.30	2.48	2.2	
LAWMA, Amerada Pass (AMRL1) (29.45N 91.34W)	24/0806	1011.6	24/1906	18 (11 m)	27	1.99	2.96	2.1	
Calcasieu Pass (CAPL1) (29.77N 93.34W)	24/1112	1009.2	25/1736	25 (12 m)	31	2.40	2.71	2.1	
Pilot's Station East, Southwest Pass (PSTL1) (28.93N 89.41W)	23/2254	1010.5	23/1000	30 (24 m)	35	1.74		1.9	
Lake Charles (LCLL1) (30.22N 93.22W)	23/2300	1011.3				2.06	2.59	1.9	
Bulk Terminal (BKTL1) (30.19N 93.30W)						2.22	2.51	1.8	
Grand Isle (GISL1) (29.26N 89.96W)			24/2018	18 (9 m)	26	1.34		1.3	

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)				
Port Fourchon, Belle Pass (PTFL1) (29.11N 90.20W)						1.37		1.2	
Berwick, Atchafalaya River (TESL1) (29.67N 91.24W)			23/1930	20 (13 m)	28	1.22	3.17	1.0	

[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] For most locations, 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. Values with an asterisk (*) indicate that the station is non-tidal, and the value is referenced to Mean Sea Level (MSL).
[i] Incomplete.
[**] Data not verified.

Table 4. Selected rainfall totals in Mexico associated with Hanna for the three-day period 25-27 July 2020.

Location	Total rain (in)	Location	Total rain (in)
Monterrey (25.68N 100.27W)	21.91	Pueblo Anáhuac (25.80N 97.80W)	8.00
Cadereyta (25.59N 99.98W)	17.07	Cerralvo (26.09N 99.61W)	7.94
El Canadá (25.80N 100.28W)	16.42	Valle Hermoso (25.70N 97.80W)	7.90
Monterrey C.U. (25.73N 100.31W)	14.52	Ahualulco (22.99N 99.15W)	7.86
El Cerrito (25.52N 100.20W)	14.29	Camacho (24.88N 99.58W)	7.63
Monterrey Civil Protection (25.66N 100.33W)	14.20	Presa La Boca (25.43N 100.13W)	7.59
Ciudad Díaz Ordaz (26.24N 98.60W)	14.00	Las Adjuntas (24.90N 99.68W)	7.17
Monterrey CONAGUA (25.73N 100.30W)	13.39	Las Adjuntas (24.88N 99.68W)	7.14
Reynosa (26.08N 98.29W)	12.13	Gomez Farias (23.05N 99.15W)	7.05
Micos (22.12N 99.16W)	11.98	Control (25.64N 97.82W)	6.76
El Diente (25.58N 100.31W)	11.13	Madero (26.02N 99.20W)	6.73
Arroyo Seco (25.63N 100.34W)	10.75	Obispo (25.70N 100.54W)	6.70
Santa Catarina (25.67N 100.45W)	10.42	José López Portillo (24.94N 99.40W)	6.57
Montemorelos (25.17N 99.83W)	10.08	La Servilleta (22.83N 99.12W)	6.41
Las Enramadas (25.50N 99.53W)	9.92	Carmen de los Elizondo Linares (24.98N 99.44W)	6.24
Rodrigo Gómez (25.43N 100.13W)	9.89	Méndez (24.98N 99.44W)	6.18
Camacho (24.87N 99.58W)	9.53	Matamoros (25.83N 97.52W)	5.98
Río Bravo (25.97N 98.00W)	9.20	Matamoros (25.89N 97.52W)	5.96
Sabinas (23.02N 99.09W)	9.14	Camargo (26.25N 98.80W)	5.80
Cuchillo-Solidaridad (25.71N 99.28W)	8.46	Mier (26.43N 99.15W)	5.60
Miguel Alemán (26.37N 99.04W)	8.38	San Gabriel (23.08N 98.99W)	5.58
Villa Cárdenas (25.91N 97.80W)	8.07	Saca de Agua (22.78N 98.87W)	5.56

Location	Total rain (in)	Location	Total rain (in)
La Pamona (24.99N 99.22W)	5.28	Cándido Aguilar (25.03N 98.81W)	4.22
La Encantada (23.38N 99.08W)	5.27	Salinillas (27.43N 100.37W)	4.17
Las Tinajas (25.50N 100.35W)	4.78	Venustiano Carranza (27.52N 100.62W)	4.17
Candela (26.84N 100.66W)	4.76	Nueva Apolonia (22.49N 98.63W)	4.16
Cabezones (24.99N 99.74W)	4.53	Santa Rosa (22.02N 99.06W)	4.15
Ciudad Mante (22.74N 98.98W)	4.39	Magueyes (24.57N 99.55W)	4.09
Naranjos (22.52N 99.32W)	4.36	Galeana (24.83N 100.08W)	4.03
Saltillo (25.38N 101.02W)	4.30	Marte R. Gómez (26.20N 98.93W)	4.00
E.C. Saltillo (25.44N 100.92W)	4.23		

Table 5. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	60	90
Medium (40%-60%)	12	36
High (>60%)	6	6

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Hanna, 23–26 July 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	**20.9**	**21.1**	**31.4**	**50.3**	**67.4**	105.7		
OCD5	29.4	61.1	110.2	192.8	295.2	399.9		
Forecasts	14	12	10	8	6	4		
OFCL (2015-19)	24.1	36.9	49.6	65.1	80.7	96.3	133.2	171.6
OCD5 (2015-19)	44.7	96.1	156.3	217.4	273.9	330.3	431.5	511.9

Table 6b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Hanna, 23–26 July 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 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	20.0	18.4	29.1	49.9	66.1	91.4		
OCD5	27.7	58.8	106.2	184.7	282.8	442.3		
GFSI	21.8	30.6	45.9	64.6	113.3	164.5		
HMNI	25.8	33.9	45.4	73.2	109.2	137.9		
HWFI	23.0	29.8	42.7	73.5	107.5	151.8		
EMXI	20.1	26.9	38.1	**45.0**	**47.9**	**12.4**		
CMCI	25.8	37.5	49.3	78.5	103.7	**89.4**		
NVGI	29.3	42.5	60.7	81.9	102.5	112.7		
CTCI	24.6	41.7	61.7	103.8	145.1	144.5		
AEMI	20.1	26.3	37.7	**48.6**	**64.8**	**17.3**		
HCCA	**19.3**	22.4	29.3	**37.8**	**49.8**	**80.9**		
TVCX	**18.4**	21.5	30.2	**48.2**	**65.2**	**71.3**		
GFEX	**18.7**	25.0	34.7	**49.3**	74.4	**77.6**		
TVCA	**18.7**	21.1	31.1	50.8	70.7	**84.4**		
TVDG	**17.5**	21.4	29.7	**47.1**	69.1	**77.1**		
TABD	26.6	36.5	48.1	83.4	112.5	117.8		
TABM	34.9	59.0	83.1	119.7	141.5	213.5		
TABS	55.5	111.9	170.0	226.3	264.7	402.5		
Forecasts	13	11	9	6	4	1		

Table 7a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Hanna, 23–26 July 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	5.4	8.8	13.5	19.4	21.7	17.5		
OCD5	5.4	10.1	13.3	13.2	17.0	21.5		
Forecasts	14	12	10	8	6	4		
OFCL (2015-19)	5.2	7.7	9.4	10.7	11.9	13.0	14.4	15.5
OCD5 (2015-19)	6.8	10.8	14.1	17.0	18.8	20.6	22.5	24.6

Table 7b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Hanna, 23–26 July 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 7a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	5.8	9.1	13.9	17.5	22.5	0.0		
OCD5	5.8	11.0	14.3	**11.7**	**15.5**	20.0		
GFSI	12.0	20.2	27.7	28.7	38.0	12.0		
HMNI	7.6	11.5	14.1	**16.8**	28.8	4.0		
HWFI	7.5	9.8	15.2	21.8	27.0	2.0		
EMXI	12.9	19.5	24.7	26.8	37.0	2.0		
DSHP	6.8	12.3	17.4	18.8	25.8	0.0		
LGEM	6.1	13.3	19.0	21.0	27.8	0.0		
ICON	6.3	11.2	15.7	19.3	27.0	0.0		
IVCN	6.6	11.5	16.3	19.5	26.5	1.0		
IVDR	7.3	12.1	16.8	20.2	27.5	2.0		
CTCI	8.4	13.4	18.4	19.2	24.2	4.0		
HCCA	**4.9**	**8.5**	**13.2**	**16.5**	23.0	2.0		
Forecasts	13	11	9	6	4	1		

Table 8. Storm surge watch and warning summary for Hurricane Hanna, 23–26 July 2020.

Date/Time (UTC)	Action	Location
24 / 2100	Storm Surge Warning issued	Baffin Bay to Sargent, Texas
25 / 0900	Storm Surge Warning issued	Port Mansfield to Baffin Bay
26 / 0300	Storm Surge Warning discontinued	Port O'Connor to Sargent
26 / 0600	Storm Surge Warning discontinued	Port Aransas to Port O'Connor
26 / 0900	Storm Surge Warning discontinued	All

Table 9. Coastal wind watch and warning summary for Hurricane Hanna, 23–26 July 2020.

Date/Time (UTC)	Action	Location
23 / 0300	Tropical Storm Watch issued	Port Mansfield to High Island
23 / 2100	Tropical Storm Watch modified to	San Luis Pass to High Island
23 / 2100	Tropical Storm Warning issued	Port Mansfield to San Luis Pass
24 / 0300	Tropical Storm Warning modified to	Texas/Mexico Border to San Luis Pass
24 / 1500	Tropical Storm Watch discontinued	All
24 / 2100	Hurricane Warning issued	Baffin Bay to Mesquite Bay
24 / 2100	Tropical Storm Warning modified to	Texas/Mexico Border to Baffin Bay
24 / 2100	Tropical Storm Warning modified to	Mesquite Bay to San Luis Pass
25 / 0300	Hurricane Warning modified to	Port Mansfield to Mesquite Bay
25 / 0300	Tropical Storm Warning modified to	Mesquite Bay to High Island
25 / 0300	Tropical Storm Warning issued	Barra el Mezquital Mexico to the Texas/Mexico Border
25 / 0300	Tropical Storm Warning discontinued	Texas/Mexico Border to Port Mansfield
25 / 1500	Tropical Storm Warning discontinued	Sargent to High Island
25 / 2100	Hurricane Warning modified to	Port Mansfield to Port Aransas
25 / 2100	Tropical Storm Warning discontinued	Port O’Conner to Sargent
25 / 2100	Tropical Storm Warning issued	Port Aransas to Port O’Connor
26 / 0300	Hurricane Warning modified to	Port Mansfield to Baffin Bay
26 / 0300	Tropical Storm Warning modified to	Baffin Bay to Port O’Connor

Date/Time (UTC)	Action	Location
26 / 0600	Hurricane Warning discontinued	All
26 / 0600	Tropical Storm Warning modified to	Barra el Mezquital to Port O'Connor
26 / 0900	Tropical Storm Warning discontinued	Baffin Bay to Port O'Connor
26 / 1500	Tropical Storm Warning discontinued	TX/Mex Broder to Baffin Bay
26 / 1800	Tropical Storm Warning discontinued	All

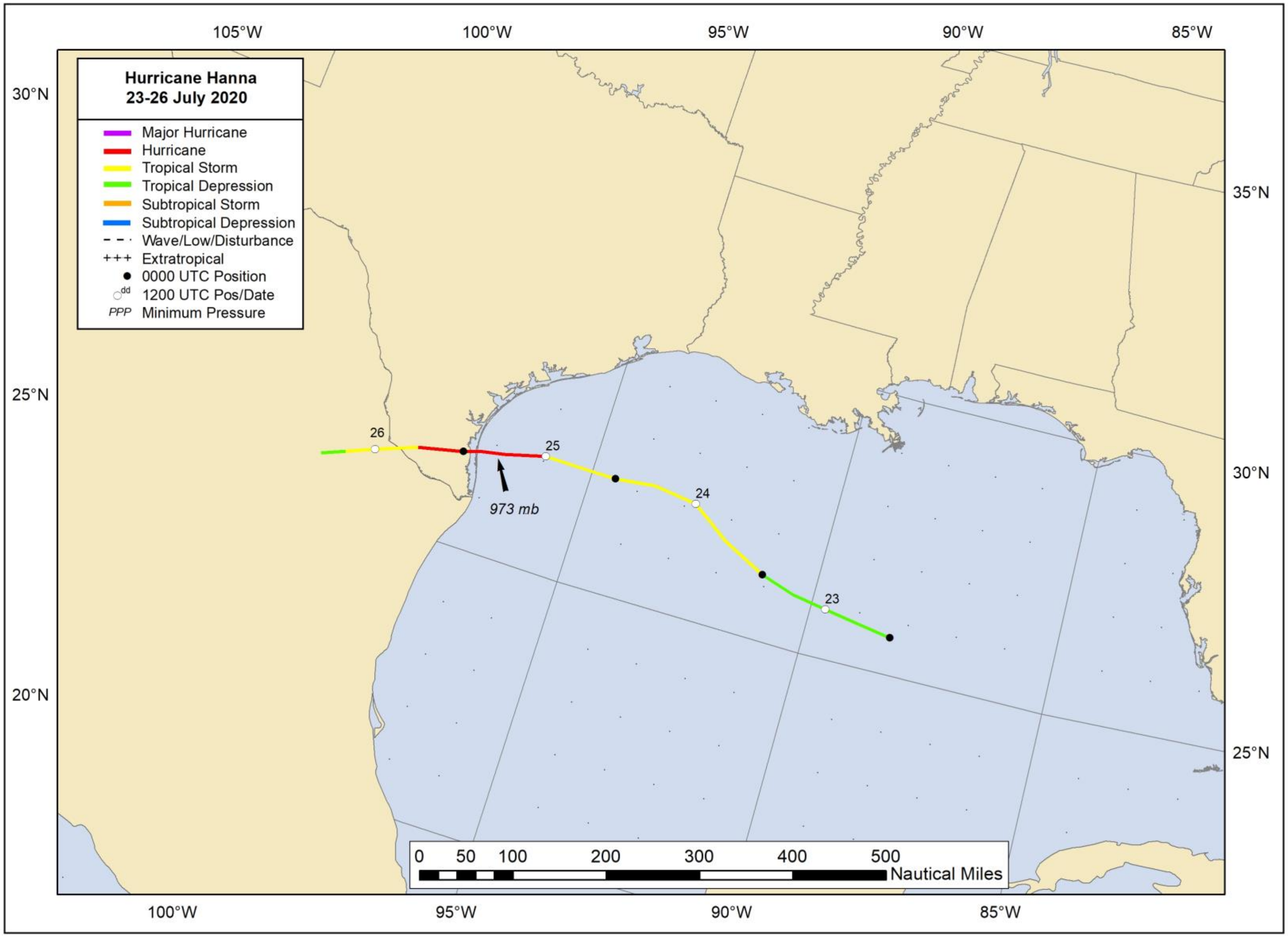

Figure 1. Best track positions for Hurricane Hanna, 23–26 July 2020.

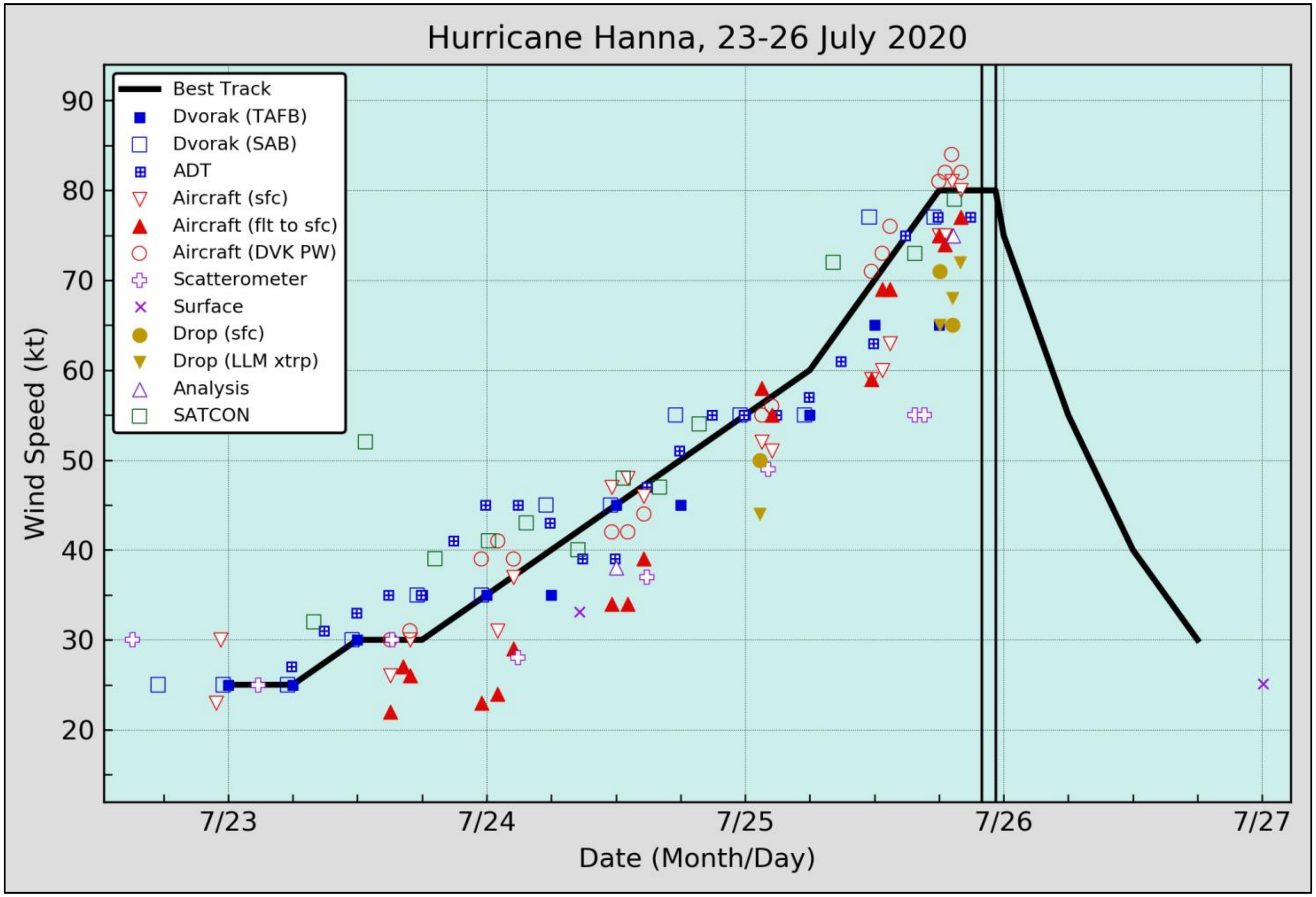

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Hanna, 23–26 July 2020. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde 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 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, and solid vertical lines correspond to landfalls.

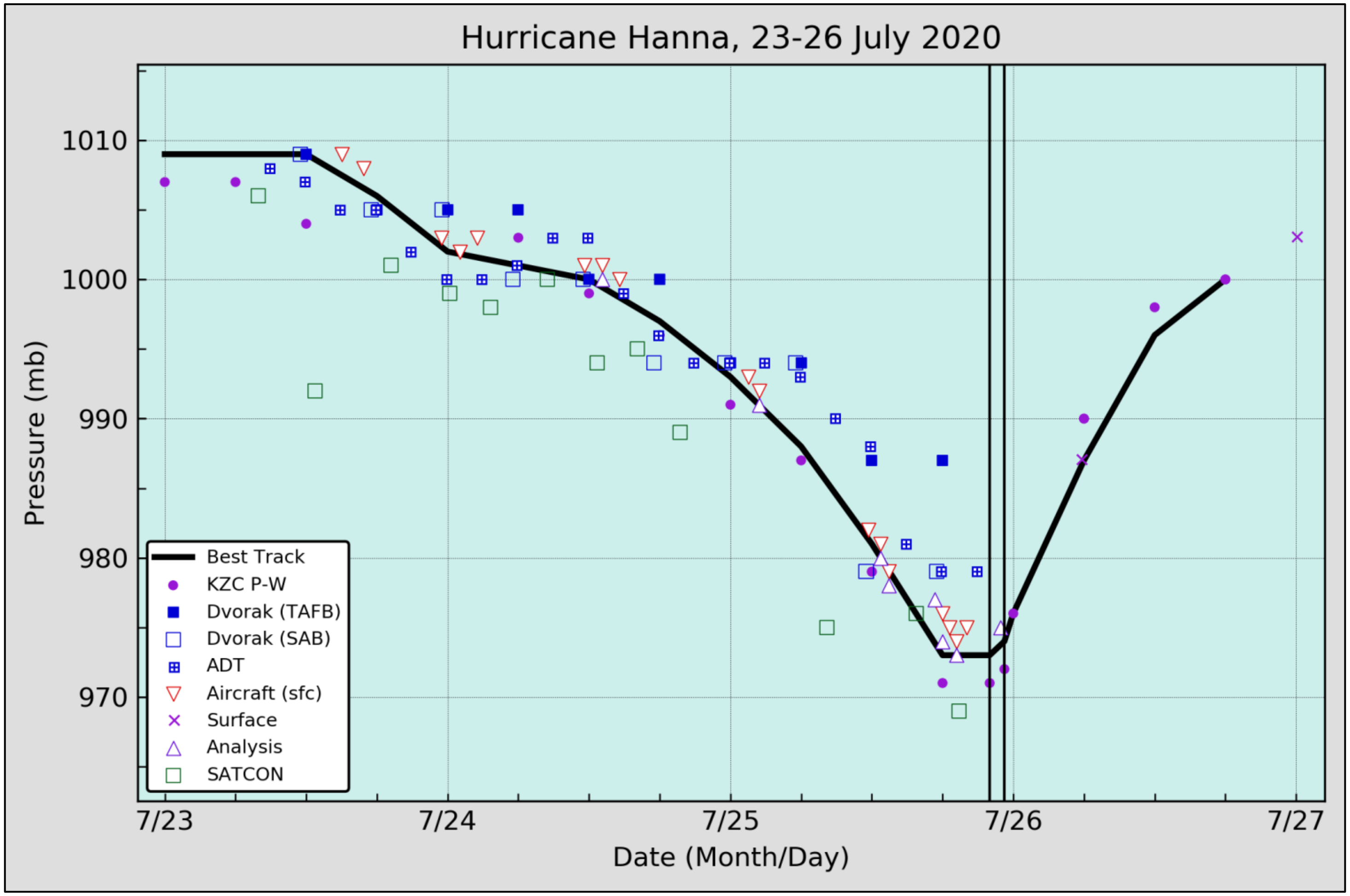

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Hanna, 23–26 July 2020. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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, and solid vertical lines correspond to landfalls.

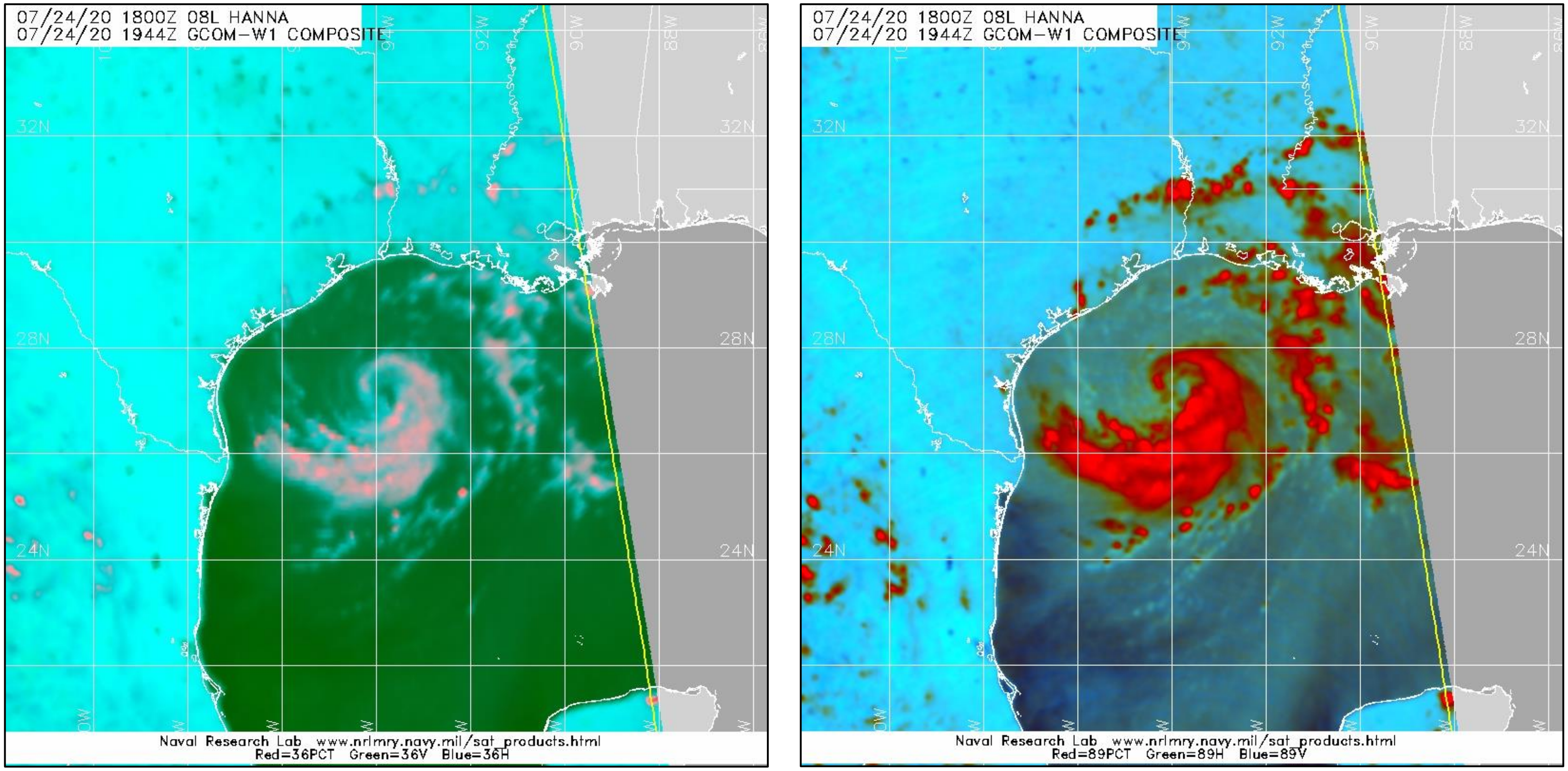

Figure 4. GCOM-W1 AMSR-2 microwave images of Hanna at 1944 UTC 24 July 2020. Note the development of a low- to mid-level eye and excellent banding features in both the 36-GHz (left) and 89-GHz (right) color composite microwave images.

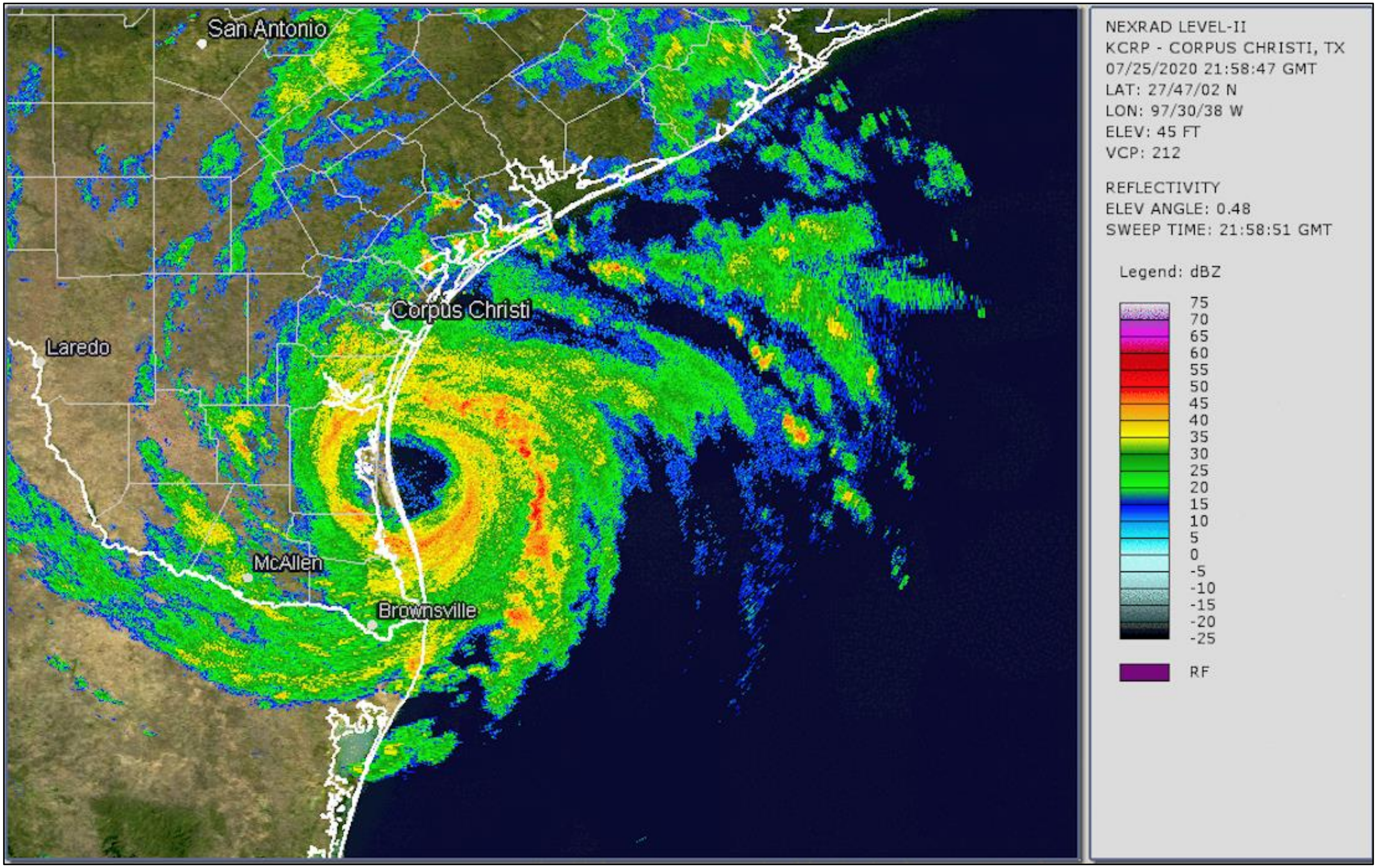

Figure 5. NWS WSR-88D radar image of Hurricane Hanna at 2158 UTC 25 July 2020 near the time of landfall on Padre Island, Texas. Image courtesy Brian McNoldy, University of Miami.

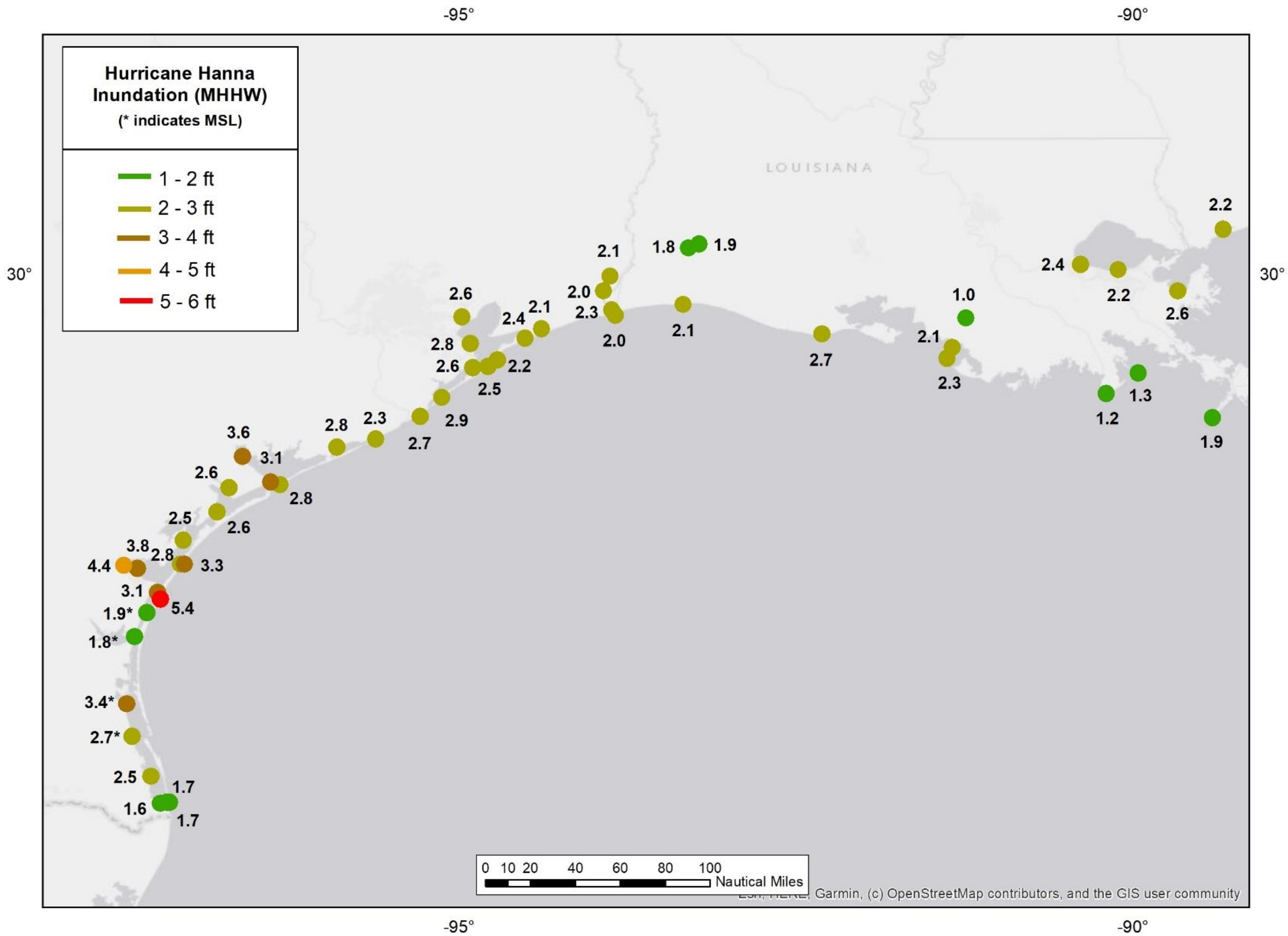

Figure 6. Maximum water levels measured from tide gauges during Hurricane Hanna. Water levels are referenced as feet above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. Data from non-tidal stations are referenced above Mean Sea Level (MSL) and are marked by an asterisk (*).

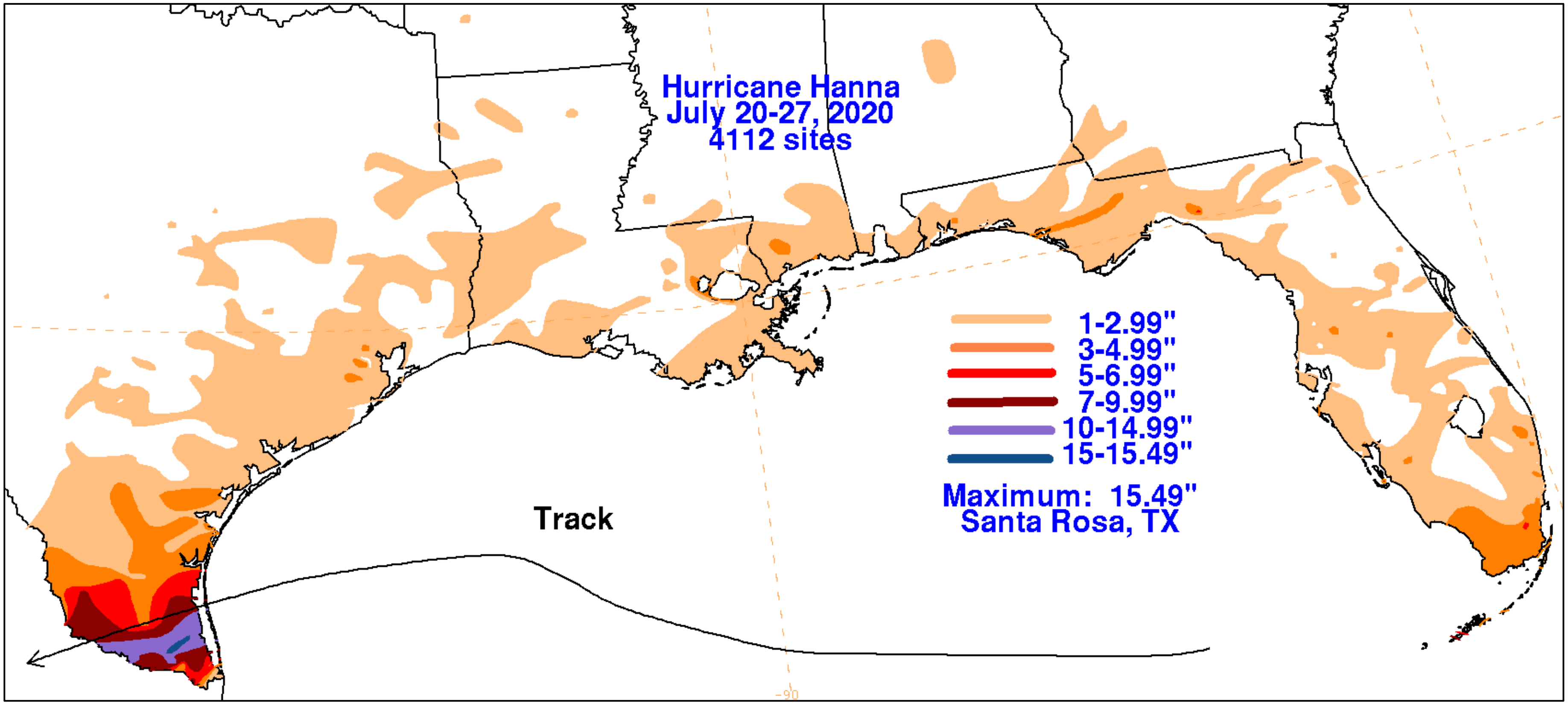

Figure 7. Observed rainfall (inches) from Hurricane Hanna and its precursor disturbance over the southern United States. Image courtesy of David Roth from NOAA's Weather Prediction Center.

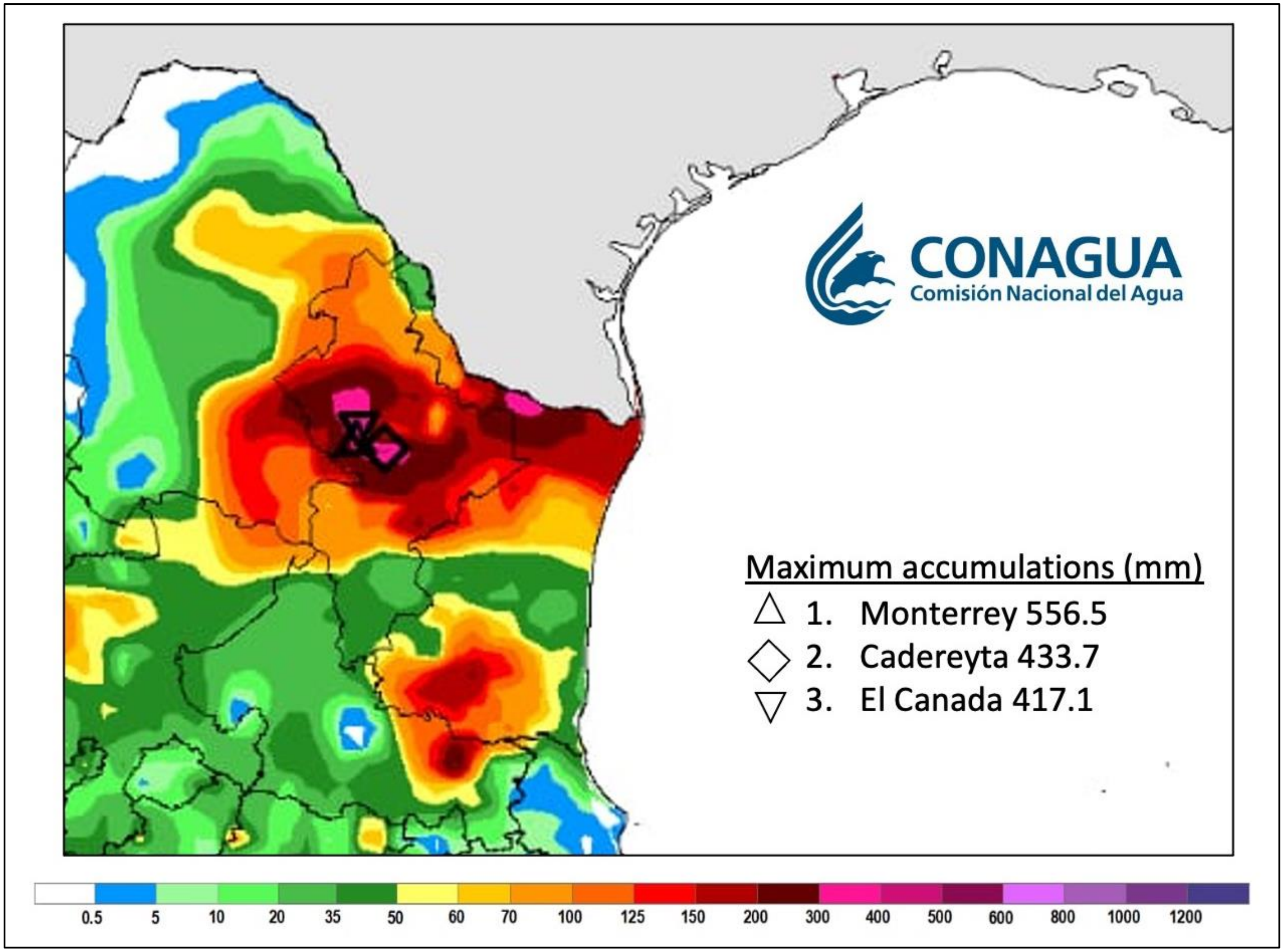

Figure 8. Observed rainfall (mm) from Hurricane Hanna and its remnants over northeastern Mexico during the period 25–27 July 2020. Image courtesy of Mexico's Comissión Nacional del Agua (CONAGUA).

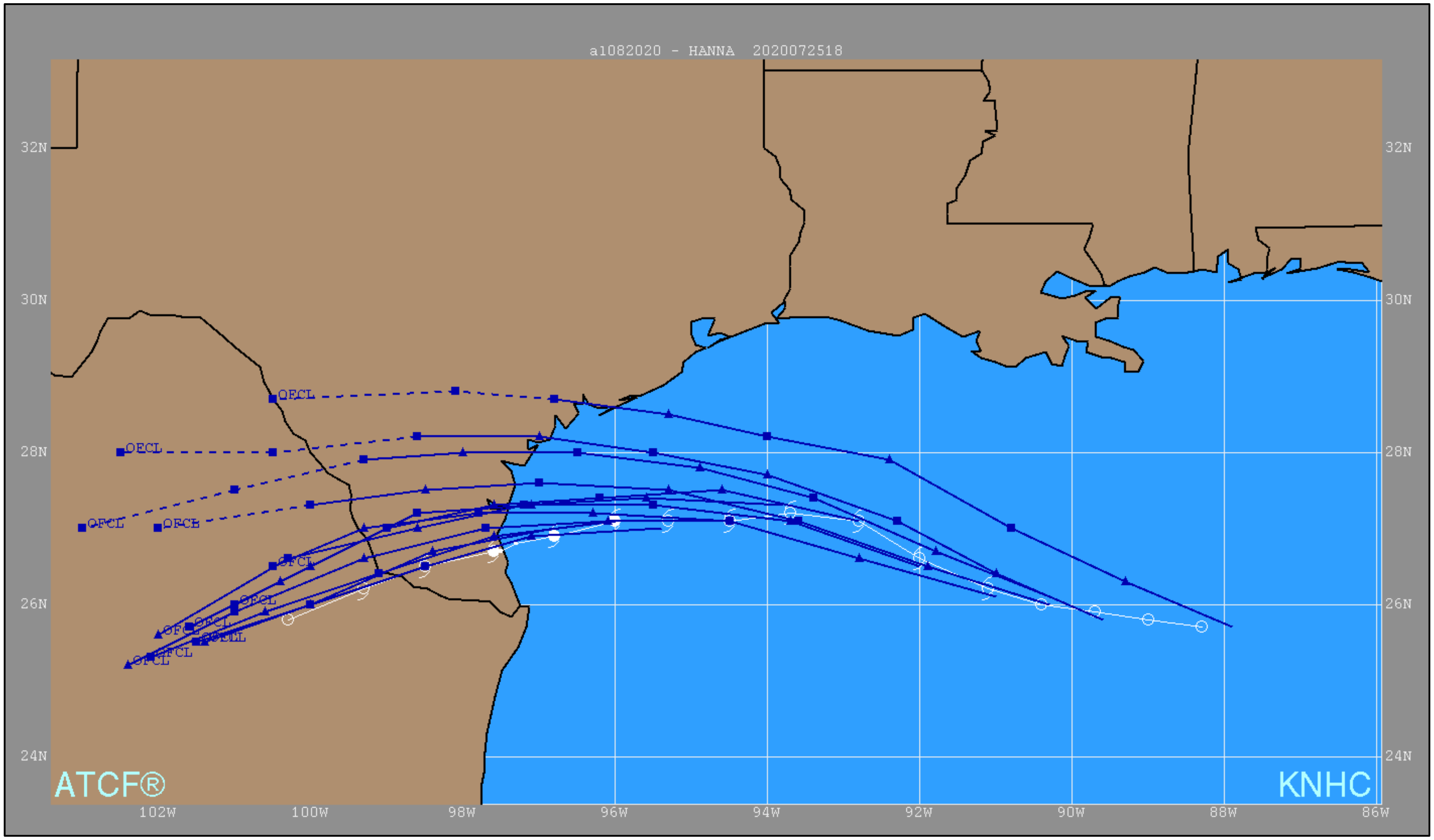

Figure 9. NHC official track forecasts (solid blue lines) for Hurricane Hanna, 23–26 July 2020. The best track is given by the solid white line with positions given at 6-h intervals. Note the poleward (northward) bias of the NHC track forecasts, especially with the first few forecasts issued on 23 July.

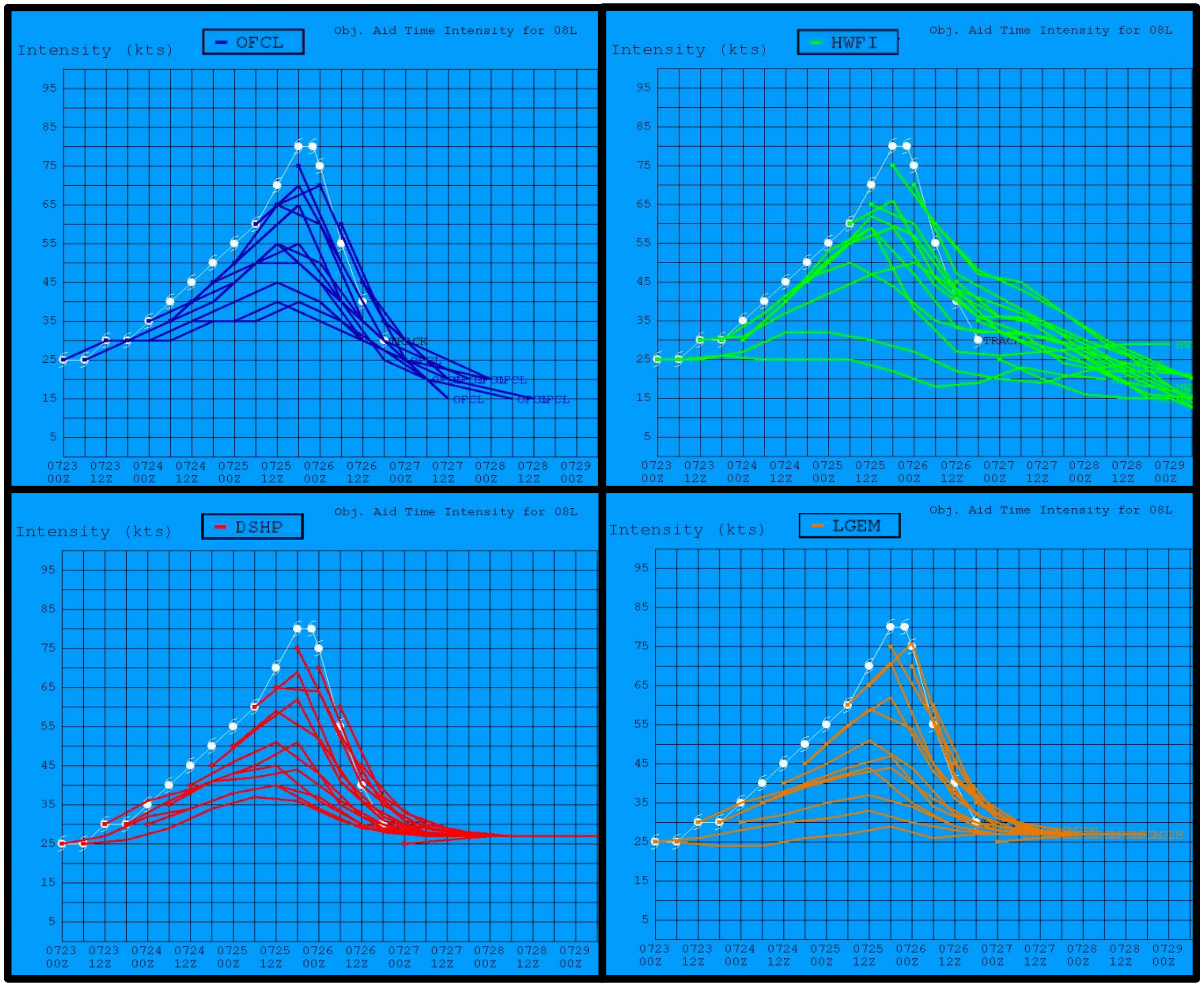

Figure 10. NHC official intensity forecasts (upper left - blue lines), HWFI intensity forecasts (upper right - green lines), DSHP intensity forecasts (lower left – red lines), and LGEM intensity forecasts (lower right – orange lines) in knots for Hurricane Hanna. The best track is given by the solid white line with intensities (kt) given at 6-h intervals. Note the under-forecast bias of the official forecast (OFCL) and the guidance shown here.

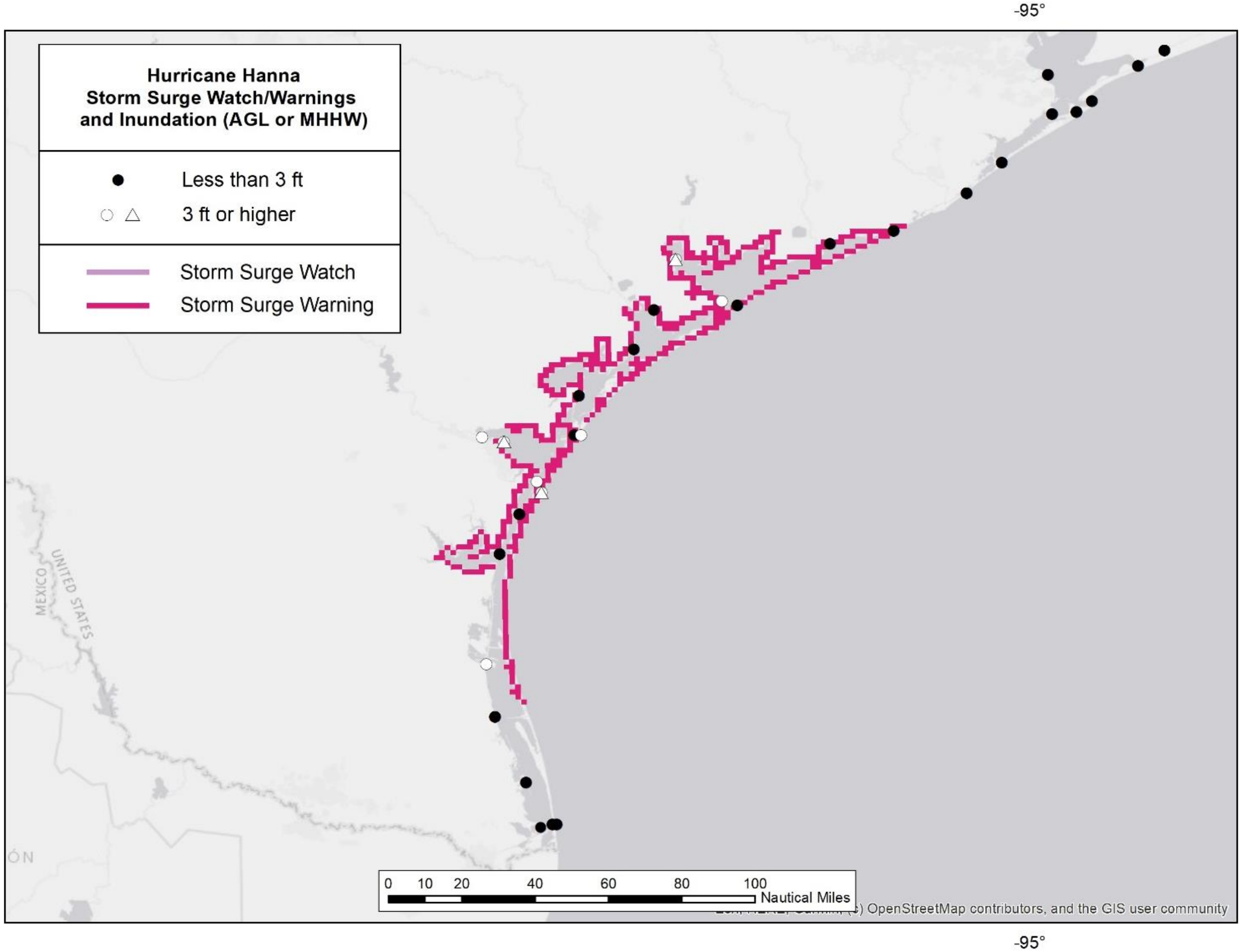

Figure 11. Maximum water levels measured during Hurricane Hanna from tide gauges (circles) and surveyed high water marks (triangles), and areas covered by storm surge watches (lavender) and warnings (magenta). Water levels from tide gauges are referenced as feet above Mean Higher High Water (MHHW) or Mean Sea Level (MSL), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. High water marks are referenced as feet above ground level. 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.