NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE NICHOLAS

(AL142021)

12–15 September 2021

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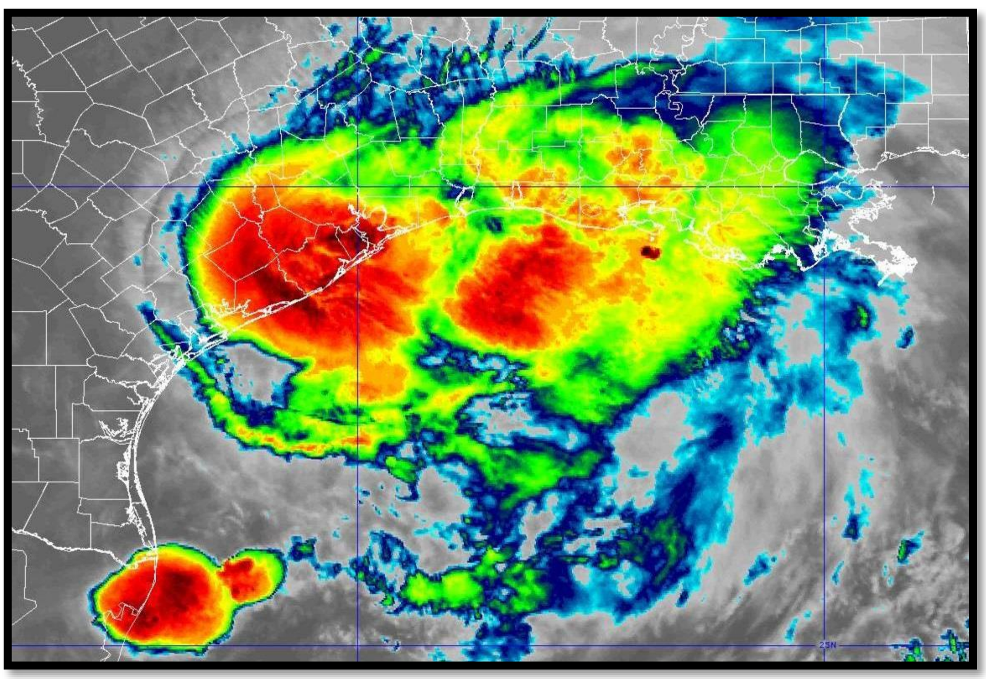
29 March 2022[1]



GOES-16 8.5-µm COLOR INFRARED SATELLITE IMAGE OF HURRICANE NICHOLAS NEAR THE TIME OF LANDFALL ALONG THE TEXAS COAST AT 0530 UTC 14 SEPTEMBER 2021. IMAGE COURTESY NOAA/NESDIS/STAR.

Nicholas was a Category 1 hurricane (on the Saffir Simpson Hurricane Wind Scale) that made landfall on the eastern portion of the Matagorda Peninsula in Texas. The cyclone then moved slowly over eastern Texas and Louisiana while weakening, producing heavy rainfall and flooding across a large portion of the southeastern United States.

[1] Original report dated 1 March 2022. This version corrects an error in Table 1.

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Hurricane Nicholas

12–15 SEPTEMBER 2021

SYNOPTIC HISTORY

The origin of Nicholas can be traced back to a tropical wave that emerged off the west coast of Africa on 28 August. The associated convection remained disorganized as the wave moved westward across the tropical North Atlantic basin through 3 September and then traversed the Caribbean Sea from 4–8 September. The wave continued westward across Central America on 9 September, leaving behind a surface trough over the western Caribbean Sea. The trough reached the southwestern Gulf of Mexico by 11 September, and a small area of convection developed just to its west late that day. Convection quickly increased and began to show signs of organization early on 12 September as the disturbance moved northwestward. By 1200 UTC that day, satellite images and data from an Air Force Reserve Hurricane Hunter aircraft indicated that the system had a sufficiently well-defined low-level circulation to be designated a tropical cyclone. The aircraft also revealed that the system was producing sustained surface winds of tropical storm force at that time, marking the formation of Tropical Storm Nicholas about 115 n mi northeast of Veracruz, Mexico. 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[2].

For the first 24 h after formation, Nicholas moved generally north-northwestward around a subtropical ridge located over the southeastern United States. At times, this motion appeared erratic, as early on there were multiple low-level swirls embedded within a larger mean circulation. In addition, the center of Nicholas appeared to re-form at least twice while it was over the western Gulf of Mexico. Despite this disorganization amid the presence of moderate south-southwesterly vertical wind shear, the storm strengthened over warm waters and within a very moist and unstable atmospheric environment. The cyclone turned northward and then north-northeastward toward a weakness in the subtropical ridge on 13 September, which took Nicholas on a path toward the central Texas coast. The strengthening trend continued, and Doppler radar velocity data indicated that Nicholas became a 65-kt hurricane by 0000 UTC 14 September when it was located about 25 n mi south-southwest of Matagorda, Texas. Nicholas continued north-northeastward and made landfall at 0530 UTC on the eastern portion of the Matagorda Peninsula with maximum winds of about 65 kt, less than 10 n mi west-southwest of Sargent Beach.

The forward motion of Nicholas slowed around the time of landfall as the steering flow surrounding the cyclone began to break down. The hurricane weakened as it moved inland, and Nicolas became a tropical storm by 1200 UTC 14 September while located about 25 n mi south-

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[2] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year’s storms are located in the *btk* directory, while previous years’ data are located in the *archive* directory.

southwest of Houston. The storm weakened quickly over land that day as it moved slowly northeastward to east-northeastward. By 0000 UTC 15 September, Nicholas weakened to a tropical depression about 20 n mi west of Port Arthur, Texas. The depression passed over southern Louisiana that day, and the combination of dry air and strong westerly vertical wind shear stripped away its associated deep convection and mid-level circulation to its east. By 1800 UTC, Nicholas degenerated into a remnant low about 20 n mi west of Lafayette, Louisiana. The remnant low then meandered over south-central Louisiana for the next 24 h, and briefly emerged over the extreme northern Gulf of Mexico early on 16 September. However, the unfavorable environmental conditions prevented regeneration of organized deep convection. The low began moving slowly northwestward late on 16 September, and this motion continued into 17 September. By 1200 UTC that day, surface observations and satellite images indicated that the low-level circulation was no longer well defined, and it is estimated that Nicholas dissipated over southwestern Louisiana by that time. The remnants meandered over the region until 20 September, at which time they were absorbed by a mid-latitude trough and associated cold front.

METEOROLOGICAL STATISTICS

Observations in Nicholas (Figs. 2 and 3) include subjective satellite-based Dvorak and intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), 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. 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 Nicholas. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from 4 flights (15 center fixes) by the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve (USAF) from 12–14 September. Radar data from the National Weather Service WSR-88D radars in Brownsville, Corpus Christi, and Houston, Texas, as well as Lake Charles, Louisiana, were also beneficial in tracking Nicholas.

Ship reports of winds of tropical storm force associated with Nicholas are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Winds and Pressure

The peak intensity of Nicholas of 65 kt beginning at 0000 UTC 14 September through landfall in Texas that night, is based on a combination of Doppler radar data from Houston and surface and aircraft observations. Four-bin average Doppler radar velocities of 74 and 78 kt at 8200 and 8550 ft above sea level (ASL), respectively, were sampled within strong convection (Fig. 4) at 2323 UTC 13 September. Within a typical thermodynamic and mixing environment of a tropical cyclone, these wind speeds would reduce to 64 and 68 kt at the surface, respectively. At 0001 UTC, the radar sampled a four-bin average of 81 kt at 7500 ft ASL (Fig. 5), which reduces to 69 kt at the surface. Although these radar estimates suggest that the intensity of Nicholas could have been closer to 70 kt, the convective cells supporting these winds were somewhat transient. In addition, from 2332 UTC 13 September to 0137 UTC 14 September, a mean of the adjusted radar velocities in this same rainband (not shown) is 64 kt. Thus, the peak intensity of Nicholas is estimated to be 65 kt. This intensity was also supported by a USAF aircraft that reported a peak 850-mb flight-level wind of 80 kt (reduces to 64 kt at the surface) and an SFMR wind of 63 kt. The highest wind report on land was at a Weatherflow station (XMGB) on Matagorda Island, Texas (Table 3) that reported a 6-m sustained wind of 66 kt at 0238 UTC as the eyewall of Nicholas neared the station.

The minimum pressure of 988 mb at 0000 UTC 14 September is based on an aircraft dropsonde at 0005 UTC into the center of Nicholas that measured a surface pressure of 989 mb with 13-kt winds. The landfall pressure of 991 mb is based on an observed surface pressure of 994.9 mb at a weather station in East Matagorda with a sustained wind of 35 kt at that time. In Sargent, a minimum pressure of 993.2 mb was observed as the center of Nicholas passed near the station at 0600 UTC, with sustained winds of 19 kt at the time of the observation. At 0501 UTC an aircraft dropsonde into the hurricane's center measured a surface pressure of 992 mb with 8-kt winds.

On 13 September, the day prior to Nicholas making landfall, the cyclone's path took the center within about 50 n mi of the northern portion of Mexico's east coast and the coast of southeastern Texas. At 0942 UTC that day, a 34-kt sustained wind was observed at Brazos Santiago, just north of the Mexico/Texas border. In Playa Bagdad, Mexico, a wind gust to 37 kt was reported just a few moments later. Tropical storm conditions spread northward along the Texas coast throughout the day, well before landfall. A Texas Coastal Ocean Observing Network (TCOON) station at Aransas Wildlife Refuge reported a sustained wind of 36 kt with a gust to 46 kt at 2224 UTC. There were numerous other locations along the southeastern Texas coast that reported wind gusts of 34 to 45 kt.

The strongest winds in Texas occurred along the stretch of coastline near where the eyewall of Nicholas came ashore. The WeatherFlow station (XMGB) on Matagorda Island (66 kt at 6 m, Table 3) reported the highest sustained wind on land at 0238 UTC 14 September, approximately 3 h prior to the center making landfall. This station also reported a peak wind gust of 82 kt. There were no other land stations that reported sustained winds of hurricane force. However, several observing sites along the Texas coast from Port O'Connor to Freeport Harbor reported wind gusts of hurricane force. A TCOON station at Port O'Connor reported a sustained wind of 56 kt and a gust to 67 kt. A weather station at Palacios Municipal Airport reported a sustained wind of 48 kt and a gust to 67 kt. Another TCOON site located in East Matagorda measured a sustained wind of 59 kt and a gust to 66 kt. A National Ocean Service (NOS) site at the entrance to Matagorda Bay measured a sustained wind of 59 kt and a gust to 72 kt. At Freeport Harbor, a TCOON station reported a sustained wind of 57 kt and a gust to 74 kt.

After landfall on 14 September, Nicholas's wind field did not penetrate very far inland over Texas. The northernmost observations of sustained tropical-storm-force winds in Texas were at Morgan's Point (43 kt) and Houston Hobby Airport (34 kt) at 0954 and 0753 UTC, respectively. The center of the tropical storm remained just inland as it moved northeastward to east-northeastward across northeast Texas, spreading tropical storm conditions along portions of that coastline and into southwestern Louisiana. A NOS station at Eagle Point reported sustained winds of 41 kt and a gust to 53 kt. At High Island, a TCOON station measured a sustained wind of 34 kt and a gust to 42 kt. In Louisiana, a NOS station at Calcasieu Pass measured a sustained wind of 37 kt with a gust to 43 kt. At Texas Point, near the Louisiana/Texas border, a sustained wind of 41 kt and gust to 54 kt was reported at 1700 UTC.

Storm Surge[3]

The highest measured storm surge from Nicholas was 4.30 ft above normal tide levels at a NOS tide gauge at Morgans Point, Texas, at the entrance of the Houston Ship Channel in Galveston Bay. A storm surge of 4.13 ft above normal tide levels was also measured by a TCOON tide gauge at Freeport Harbor. Higher surges may have occurred between *in situ* water level gauges.

Combined with the tides, Nicholas's surge resulted in coastal inundation levels of 3 to 6 ft above ground level (AGL) along portions of the middle and upper Texas coast, generally between Port O'Connor and the Bolivar Peninsula, and along Galveston Bay. The highest inundation occurred in parts of Brazoria, Galveston, and Harris Counties. Table 3 and Figure 6 provide observations from various tide stations, stream gauges, and surveyed high water marks along the western and central U.S. Gulf coast. A United States Geological Survey (USGS) water level gauge on the Old Brazos River in Freeport, Texas, measured a peak water level of 5.5 ft above Mean Higher High Water, indicating that unprotected areas outside of the Freeport Hurricane-Flood Protection Levee System, including along the Gulf Intracoastal Waterway, likely experienced inundation as high as 5 to 6 ft AGL. In addition, a National Weather Service (NWS)/Harris County Flood Control District (HCFCD) team surveyed high water marks of 5.4 ft, 5.2 ft, and 5.1 ft AGL at Jamaica Beach, Treasure Island (near San Luis Pass) (Fig. 7), and Sylvan Beach, respectively. A storm surge hindcast produced by the NHC Storm Surge Unit (not shown) confirms inundation levels as high as 6 ft AGL in these areas.

A TCOON gauge in the Manchester section of Houston recorded a peak water level of 6.0 ft MHHW, but being located along the Houston Ship Channel/Buffalo Bayou, that station likely experienced a combination of storm surge and freshwater runoff from Nicholas's heavy rainfall. The NWS/HCFCD team surveyed a high water mark of 5.8 ft AGL at the mouth of Brays Bayou at the Houston Ship Channel, but flooding at that location was also likely due to a combination of storm surge and freshwater flooding.

Peak water levels of 1 to 3 ft AGL occurred elsewhere along the Texas coast south of Port O'Connor and north of the Bolivar Peninsula, as well as along the coasts of Louisiana and

[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). **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).

Mississippi. In Mississippi, a maximum water level of 3.3 ft MHHW was recorded by the NOS tide gauge at the Bay Waveland Yacht Club on the periphery of Nicholas's circulation, about 12 h after the storm had become a tropical depression. In Louisiana, peak water levels of 2.7 ft and 2.6 ft MHHW were measured by NOS gauges at Amerada Pass and Shell Beach.

Rainfall and Flooding

Texas

The moisture associated with Nicholas spread across coastal sections of southeastern Texas by 12 September as the cyclone passed east of the area (Table 3, Figure 8). Rainfall amounts of 2 inches or less occurred primarily near the coast south of the Corpus Christi area, while the Corpus Christi area itself received about 3 to 4 inches. The heaviest rainfall in Texas occurred after Nicholas made landfall on 14 September when its forward motion slowed. The cyclone spent much of that day crossing the Houston/Galveston metropolitan area before nearing the Louisiana/Texas border on 15 September. Across this region, widespread rainfall of 4 to 9 inches occurred. The highest rainfall amount reported was 10.19 inches, 2 miles northwest of Freeport.

Louisiana

Rainfall from Nicholas began across portions of southern Louisiana by 13 September, nearly two days before the center of the cyclone crossed into the state (Fig. 9). The weakening cyclone meandered over the southern portion of the state from 15 September until the center became ill defined on 17 September. Even though the system was no longer a tropical cyclone after that time, some of the associated moisture lingered across the region until a frontal system lifted the remnants out of the area on 20 September. Fortunately for Louisiana, a large portion of the deep tropical moisture had been stripped away from the circulation of Nicholas by strong mid- to upper-level winds before it arrived, which caused a large portion of the heavy rainfall to spread well north and east of the cyclone's center. This spared the state from a potentially catastrophic rainfall event. Even so, 4 to 8 inches of rainfall were common across southern Louisiana. Higher rainfall amounts of 8 to 14 inches occurred across the south-central parishes, most of which occurred from late 14 into early 15 September. The highest rainfall report from the state was 17.29 inches, which occurred in Tangipahoa Parish. Across northern Louisiana, Nicholas's storm total rainfall was much lower, generally 1 to 3 inches.

Mississippi, Alabama, and Florida

Deep tropical moisture within the onshore flow well east of the center of Nicholas setup intense rain bands across Mississippi, Alabama, and the Florida Panhandle primarily from 15–18 September (Fig. 10). Rainfall amounts of 5 to 10 inches occurred across most of southern Mississippi with a maximum amount of 18.52 inches near Gulfport. Rainfall totals of 3 to 6 inches occurred in central Mississippi with lighter amounts farther north. In Alabama, 4 to 8 inches occurred across a large portion of the state, with locally higher amounts exceeding 10 inches. Much of the western Florida Panhandle received at least 4 to 10 inches of rainfall, with the highest amount of 12.66 inches occurring north of Pensacola.

Georgia and Tennessee

Southern Georgia and middle Tennessee experienced heavy rainfall from Nicholas and its remnants mainly on or after 15 September. Rainfall amounts of 3 to 7 inches were common across these areas with locally higher amounts. The highest rainfall total in Georgia was 9.74 inches in the town of Eastman. In Tennessee, a maximum storm total rainfall of 11.2 inches was reported near Pikeville.

Tornadoes

There were no tornadoes reported in association with Nicholas.

CASUALTY AND DAMAGE STATISTICS

There were two direct[4] deaths attributed to Nicholas after it made landfall. Both were caused by freshwater flooding in Alabama. A vehicle was swept away by floodwaters in Tuscaloosa, drowning a 40-year-old man. In Hazel Green, another male, 35, drowned when he was pulled into a drainage pipe. Although these deaths occurred after Nicholas had dissipated, the heavy rainfall while Nicholas was a tropical cyclone and during its remnant low phase directly contributed to this flooding. Also of note, there were two rip current deaths that occurred on the west end of Panama City Beach, Florida on 18 September. A 28-year-old male and a 9-year-old male were swept out to sea that day. Additionally, a 60-year-old man was hospitalized in critical condition on 17 September as a result of these rip currents. However, by that time, the remnant swell from Nicholas had already diminished, while the winds across the region could no longer be wholly attributed to the system. Therefore, those fatalities and the injury were not considered to be directly caused by Nicholas.

Winds, storm surge, and high surf were the primary causes of damage in Texas. Matagorda and Brazoria Counties were hardest hit, with widespread tree damage, downed trees and significant beach erosion and flooding. Moderate damage to residential roofs was also observed. Along the coast from Freeport to Corpus Christi, several piers were severely damaged or destroyed and water entered homes near the beaches. Minor to moderate beach erosion, scattered downed trees, and moderate wind damage to homes were observed in Galveston,

[4] 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.

Harris, and Fort Bend Counties. Power outages were widespread in these Texas locations, with at least 500,000 buildings without power during the passage of Nicholas.

The heavy rainfall across portions of Texas produced mainly localized flooding and flash flooding, including in Galveston's Strand District. Several roadways across Harris, Jefferson, and Orange Counties also experienced flooding. In Jefferson County, Taylor's Bayou at Craigen Road reached moderate flood stage.

Freshwater flooding was responsible for most of the damage that occurred in Louisiana, Mississippi, Alabama, Tennessee, Florida, and Georgia. This damage included roadways being washed out, vehicles damaged or destroyed in floodwaters, and homes and other structures sustaining flood damage.

In Louisiana, the heavy rainfall produced extensive flooding across southern portions of the state. In Voyelles and Evangeline Parishes, many roads were closed due to high water. In Rapides Parish, several roads were reported flooded, and the Calcasieu River at Glenmora crested at 13.25 ft, above the minor flood stage of 12 ft. St. Landry Parish experienced similar road closures, while Bayou Cocodrie near Whiteville and Bayou des Cannes near Eunice crested above moderate flood stage. Bayou Nezpique, the Mermentau River, the Vermillion River at Lafayette Surrey Street, and the Calcasieu River at Oberlin and White Oak all crested at minor flood stage. Farther east, flash flooding with road closures occurred in the parishes of east Baton Rouge, Orleans (including the New Orleans Metro Area), St. Charles, Tangipahoa, Livingston, and Washington. The flooding was particularly severe in St. Charles Parish, where water entered homes in the towns of Luling, Montz, and Bayou Gauche. Numerous roadways were flooded, leaving vehicles stranded. Some of this flooding was likely enhanced due to saturated soils from the passage of Hurricane Ida just a couple of weeks prior.

Numerous roads were flooded in and around Gulfport and Biloxi, Mississippi, with cars stranded on the roadways. Other road closures and isolated flash flooding occurred mainly across the southern and central portions of Mississippi.

Many counties across the state of Alabama reported roads impassable due to flood waters, with several vehicles swept away and many other submerged resulting in water rescues. Water was also seen entering some buildings and residences.

Flash flooding and road closures occurred in several locations across Pensacola, Florida. Flash flooding was also reported in Escambia, Santa Rosa, and Okaloosa counties in the Florida panhandle.

In Thomasville, Georgia, at least 15 vehicles were stranded in floodwaters, resulting in several water rescues. Flooding of roadways was also reported in Dodge, Pulaski, Laurens, and Washington County Georgia.

River and flash flooding occurred in several counties in central Tennessee. There were numerous road closures, stranded vehicles, and at least one water rescue. In Bedford County, a home was reported flooded, and cars were seen floating down a creek. In Davison County, Richland Creek reached moderate flood stage.

A preliminary damage estimate from the National Centers for Environmental Information (NCEI) is $1 billion in the United States.

FORECAST AND WARNING CRITIQUE

Genesis

Nicholas's genesis was well forecast in the short-term range (0–48 h) but not as well in the longer 5-day timeframe. Table 4 provides the number of hours in advance of formation associated with the first NHC Tropical Weather Outlook (TWO) forecast in each likelihood category. The tropical wave from which Nicholas formed was first introduced in the TWO and given a low (<40%) chance of genesis during the next 5 days 78 h before tropical cyclone formation occurred. The 5-day chance of genesis was raised to the medium (40–60%) and high (>60%) categories 60 h and 48 h before formation, respectively. A 2-day probability of genesis was first introduced in the low category 66 h before formation occurred. These chances were then raised to the medium and high categories 48 h and 30 h before formation, respectively. Several days prior to development, the precursor disturbance was poised to cross Belize and the Yucatan Peninsula before entering the southwestern Gulf of Mexico. While the system crossed the western Caribbean, many of the global model solutions took the disturbance west-northwestward into southern Mexico, with only a few solutions showing that the system would move over the southern Gulf of Mexico where development was possible. This created a higher-than-normal level of uncertainty and reduced lead time in the 5-day genesis forecasts.

Track

A verification of NHC official track forecasts (OFCL) for Nicholas is given in Table 5a. Official forecast track errors were slightly above the mean official errors for the previous 5-yr period at all verifying forecast times. One possible source of track error (not shown) was the unexpected center reformations that occurred while Nicholas was over the western Gulf of Mexico. A homogeneous comparison of the official track errors with selected guidance models is given in Table 5b. The GFS model (GFSI) outperformed OFCL at all verifying times except 48 h. OFCL track forecasts were better than all the models for the verifying 48-h forecasts.

Intensity

A verification of NHC official intensity forecasts for Nicholas is given in Table 6a. Official forecast intensity (OFCL) errors were lower than the mean official errors for the previous 5-yr period at all verifying forecast times. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. OFCL outperformed all of the verifying models at 12–36 h, and performed better than the majority of the models at 48 h. Most models forecast Nicholas's intensity better than OFCL at 60 and 72 h, but for a small sample size. Moderate south-southwesterly vertical wind shear was expected to limit the rate of strengthening before landfall, despite the cyclone being within a moist environment and over very warm waters. In addition, intensity guidance failed to indicate with any certainty that Nicholas would become a hurricane between the time of formation and landfall (Fig. 11). Within 12 h of landfall, Nicholas turned northward and then north-northeastward. This motion was parallel to the shear vector, which may have diminished the shear's negative effects on the storm, and may have allowed for the period of quick strengthening of the cyclone until just prior to landfall.

Storm Surge Forecasts and Warnings

Storm surge watches and warnings associated with Nicholas are given in Table 7 and indicated in Fig. 12. A Storm Surge Watch was first issued for the coast of Texas from the mouth of the Rio Grande to High Island at 1500 UTC 12 September. The portion of that area from Port Aransas to San Luis Pass, including the bays, was upgraded to a Storm Surge Warning 6 h later at 2100 UTC 12 September. The watch and warning areas were extended eastward along the upper Texas coast and southwestern Louisiana coast, including Galveston Bay, on 13 September. Sustained tropical-storm-force winds first began along the coast within the highest-impacted area by 2100 UTC 13 September, and the initial Storm Surge Watch and Warning therefore had lead times of 30 h and 24 h, respectively.

As shown in Fig. 12, nearly all water level observations along the Texas coast that recorded peak water levels of 3 ft AGL/MHHW or higher fell within the Storm Surge Warning area. A few tide and stream gauges along inland waterways outside of the warning area (e.g., in the Houston metro area) measured water levels above 3 ft MHHW, but a significant part of these water rises was due to heavy rains and thus was not purely from storm surge. The only other gauge along the northern Gulf coast that measured a peak water level of at least 3 ft MHHW but was not within a watch or warning area was at the Bay Waveland Yacht Club in Mississippi. However, coastal flooding that far east occurred on the periphery of Nicholas's circulation, and the NWS Weather Forecast Office in Slidell, Louisiana, issued a Coastal Flood Advisory for that area on 14 September.

NHC's initial peak storm surge inundation forecast issued at 1500 UTC 12 September, coincident with the issuance of the Storm Surge Watch, was 2 to 4 ft above normally dry ground somewhere between the mouth of the Rio Grande and High Island, Texas, including the intervening bays. The forecast was increased to 3 to 5 ft AGL from Port O'Connor to San Luis Pass, including Matagorda Bay, at 2100 UTC 12 September, coincident with the issuance of the Storm Surge Warning. The inundation forecast was also increased to 3 to 5 ft AGL from San Luis Pass to High Island, including Galveston Bay, at 0300 UTC 14 September. Available water level observations and a storm surge hindcast indicate that peak storm surge inundation levels fell within the forecast range but may have been slightly higher (up to 6 ft AGL) in a few locations in Brazoria, Galveston, and Harris Counties.

Wind Watches and Warnings

Wind watches and warnings associated with Nicholas are given in Table 8. A Tropical Storm Warning was issued at 1500 UTC 12 September for the coast of extreme northwestern Mexico northward to Port Aransas, Texas. This issuance coincided with the first advisory for the system. Tropical storm conditions were first reported prior to daybreak on 13 September at Brazos Santiago, Texas, near the Mexico/Texas border. These conditions spread northward within this warning segment that day, with sustained tropical-storm-force winds occurring near Port Aransas beginning by early that evening. Thus, the lead time along the southern portion of this warning was around 21 h, and the northern locations in this segment were provided a lead time near 31 h.

A Tropical Storm Watch was first issued at 1500 UTC 12 September for the area along the Texas coast from Port Aransas to High Island, Texas where Nicholas was expected to make landfall. At 2100 UTC that day, a Tropical Storm Warning was issued from Port Aransas to Freeport, Texas, and a Hurricane Watch was issued from Port Aransas to Sargent, Texas. The Hurricane Watch was expanded eastward to Freeport, and the Tropical Storm Warning was expanded eastward to High Island 6 h later. Tropical storm conditions first reached the stretch of coast that was initially under a Tropical Storm Watch by 2100 UTC 13 September, when sustained tropical-storm-force winds were reported in Port O'Connor, Texas. Therefore, a lead time of 30 h and 24 h were provided for the watch and warning, respectively. A Hurricane Warning was not issued until after there were sustained hurricane-force winds occurring along the coast. This was due in large part to the lack of model support in showing Nicholas becoming a hurricane prior to landfall.

IMPACT-BASED DECISION SUPPORT SERVICES (IDSS) AND PUBLIC COMMUNICATION

The NHC began communication with emergency managers on 13 September when Nicholas was a tropical storm over the western Gulf of Mexico through its landfall on 14 September. This communication included briefings for FEMA Headquarters. These decision support briefings were coordinated through the FEMA Hurricane Liaison Team, embedded at the NHC. Facebook Live session were also conducted during those two days. The broadcasts garnered a total of 317,300 views. The Tropical Analysis and Forecast Branch of NHC provided five live briefings to the U.S. Coast Guard District 8 in New Orleans from 12–15 September. The NHC web pages were accessed approximately 25 million times from 12–15 September.

ACKNOWLEDGMENTS

The observed data in this report came from Post Tropical Cyclone Reports (PSHs) and Local Storm Reports (LSRs) issued by various NWS Weather Forecast Offices (WFOs). The PSHs were issued by WFOs in Brownsville, Corpus Christi, and Houston/Galveston, Texas, and Lake Charles, Louisiana. LSRs were issued by the offices listed above, and the WFOs located in New Orleans, Louisiana, Jackson, Mississippi, Nashville and Morristown, Tennessee, Mobile, Birmingham, and Huntsville, Alabama, Tallahassee, Florida, and Peachtree City, Georgia. Rainfall data was collected by the NOAA Weather Prediction Center (WPC).

David Roth of WPC produced the rainfall map. Matthew Green, Tiffany O'Connor, and Chris Landsea provided the IDSS briefing information, Dennis Feltgen provided the media briefing

summary, and Rachel Zelinsky provided the web statistics. Stacy Stewart performed the radar analysis.

Table 1. Best track for Hurricane Nicholas, 12–15 September 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
12 / 1200	21.0	95.2	1008	35	tropical storm
12 / 1800	22.4	95.6	1008	35	"
13 / 0000	23.7	96.1	1007	40	"
13 / 0600	24.8	96.5	1001	50	"
13 / 1200	25.9	96.7	1000	50	"
13 / 1800	27.0	96.6	998	55	"
14 / 0000	28.0	96.2	988	65	hurricane
14 / 0530	28.7	95.7	991	65	"
14 / 0600	28.8	95.7	991	65	"
14 / 1200	29.3	95.4	999	50	tropical storm
14 / 1800	29.6	94.9	1003	35	"
15 / 0000	29.9	94.4	1003	30	tropical depression
15 / 0600	30.2	93.8	1004	30	"
15 / 1200	30.3	93.1	1006	25	"
15 / 1800	30.2	92.4	1006	25	low
16 / 0000	29.9	91.8	1006	25	"
16 / 0600	29.3	91.6	1007	20	"
16 / 1200	29.7	91.7	1007	20	"
16 / 1800	29.9	92.2	1009	20	"
17 / 0000	30.3	92.6	1009	15	"
17 / 0600	30.8	93.0	1010	15	"
17 / 1200					dissipated
14 / 0000	28.0	96.2	988	65	maximum wind and minimum pressure
14 / 0530	28.7	95.7	991	65	Landfall on Matagorda Peninsula, Texas

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Nicholas, 12–15 September 2021.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
13 / 1700	V7A255	29.0	94.2	140 / 35	1017.1
13 / 2100	V7UT6	27.5	95.4	180 / 52	1006.0
13 / 2300	V7UT7	28.5	94.7	070 / 52	1006.0
14 / 0100	V7UT6	27.7	95.2	200 / 50	1006.0
14 / 0900	V7A255	28.7	93.9	150 / 41	1008.7
14 / 1100	V7UT7	28.0	94.4	200 / 37	1004.0

Table 3. Selected surface observations for Hurricane Nicholas, 12–15 September 2021. Rainfall totals are for the period of 13–20 September 2021.

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)				
United States									
Texas									
International Civil Aviation Organization (ICAO) Sites									
Bay City Municipal AP (KBYY) (28.97N 95.86W)	14/0635	998.0	14/0435	39 (2 min, 10 m)	53				
Beaumont/Port Arthur (KBPT) (29.95N 94.02W)	14/2353	1004.1	14/1245	31 (2 min, 10 m)	45				
Brazos Oil Platform (KBQX) (28.49N 95.72W)	14/0335	992.0	14/0215	58 (25 m)	70				
Calhoun County AP (KPKV) (28.65N 96.68W)	14/0100	1006.1	14/0022	33 (2 min, 10 m)	42				
Houston Hobby AP (KHOU) (29.65N 95.28W)	14/0953	1004.3	14/0753	34 (2 min, 10 m)	50				
Galveston Scholes Field (KGLS) (29.27N 94.87W)	14/1852	1004.9	14/0432	37 (2 min, 10 m)	54				
John Dunn Helistop (KMCJ) (29.71N 95.34W)	14/1035	1002.7	14/0635	38 (2 min, 10 m)	55				
Palacios (KPSX) (28.72N 96.25W)	14/0153	1002.8	14/0132	48 (2 min, 10 m)	67				
Mustang Beach AP (KRAS) (27.81N 97.09W)	13/2155	1007.8	13/2135	28 (2 min, 10 m)	36				
Victoria Regional AP (KVCT) (28.85N 96.92W)	14/0120	1005.4	13/1803	27 (2 min, 10 m)	34				
Coastal-Marine Automated Network (C-MAN) Sites									
Port Aransas Pier (KVCT) (27.82N 97.05W)			13/1800	32 (15 m)	37				
Cooperative Observing Station (COOP) Sites									
Freeport 2 NW (DOWT2) (28.98N 95.38W)									10.19
Houston/Galveston NWS WFO (HGX) (29.47N 95.08W)									8.06
Port Isabel (PIST2) (26.06N 97.22W)									2.00
National Ocean Service (NOS) Sites									
Eagle Point (EPTT2) (29.49N 94.91W)	14/1824	1003.8	14/0848	41 (6 m)	53	3.93		4.4	

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)				
Matagorda Bay Entrance Channel (MBET2) (28.42N 96.33W)	14/0048	996.0	14/0036	59 (12 m)	72	3.25		2.8	
Morgans Point (MGPT2) (29.69N 94.98W)	14/2048	1004.5	14/0954	43 (3 m)	55	4.30		4.7	
Galveston Bay Entrance (North Jetty) (GNJT2) (29.36N 94.72W)						2.94		3.3	
Galveston Pier 21 (GTOT2) (29.31N 94.79W)						2.91		3.3	
Viola Turning Basin (VTBT2) (27.85N 97.52W)						2.30		2.5	
Bob Hall Pier / Corpus Christi (MQTT2) (27.58N 97.22W)						2.11		2.1	
Nueces Bay (NUET2) (27.83N 97.49W)						1.70		1.8	
Port Isabel (PTIT2) (26.06N 97.22W)						1.47		1.7	
MODA (MHBT2) (27.82N 97.21W)						1.56		1.4	
Rockport (RCPT2) (28.02N 97.05W)						1.23		1.4	
US Forest Service RAWS Sites									
San Bernard NWR (SRDT2) (28.86N 95.57W)			14/0529	30 (6 m)	57				
Matagorda Island (MIRT2) (28.12N 96.80W)			13/2212	24 (6 m)	40				
Texas Coast Ocean Observing Network (TCOON)									
Aransas Pass (ANPT2) (27.84N 97.04W)						1.97		1.9	
SPI Brazos Santiago (BZST2) (26.07N 97.15W)	13/1100	1006.4	13/0942	34 (2 min, 10 m)	40	1.31		1.5	
Realitos Peninsula (RLIT2) (26.26N 97.29W)	13/1306	1007.8	13/0930	28 (2 min, 10 m)	35	1.23		1.4	
High Island (HIST2) (29.60N 94.39W)	14/2106	1003.3	14/0942	34	42	2.71		2.9	
Port O'Connor (PCNT2) (28.45N 96.40W)	14/0030	998.2	14/0036	56 (9 m)	67	3.79		3.2	
Manchester (NCHT2) (29.73N 95.27W)						5.58*		6.0*	
Aransas Wildlife Refuge (AWRT2) (28.23N 96.79W)	13/2348	1004.1	13/2224	36	46	2.58		2.4	
East Matagorda (EMAT2) (28.71N 95.91W)	14/0506	994.9	14/0236	59 (8 m)	66	3.45		3.3	

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)				
Freeport Harbor SPIP (FPST2) (28.94N 95.29W)	14/0630	998.6	14/0424	57 (15 m)	74	4.13		4.7	
Galveston North Jetty (GNJT2) (29.36N 94.72W)	14/1906	1002.9	14/0536	50 (12 m)	60				
Galveston RR Bridge (GRRT2) (29.30N 94.90W)	14/1612	1004.0	14/0700	41 (11 m)	51	3.35		3.8	
San Luis Pass (LUIT2) (29.08N 95.12W)	14/0724	1002.5	14/0524	42	55	3.82		4.3	
Port Lavaca (VCAT2) (28.64N 96.61W)	14/0042	1005.3	13/2218	32	45	3.20		2.3	
Port Aransas (RTAT2) (27.84N 97.07W)	13/2136	1006.1	13/1806	30 (11 m)	38	2.14		1.8	
Rollover Pass (RLOT2) (29.52N 94.51W)	14/2030	1003.1	14/1012	44 (11 m)	55	3.48		3.7	
Rockport (RCPT2) (28.02N 97.05W)	14/2212	1006.8	13/1542	25 (11 m)	35				
Packery Channel (PACT2) (27.63N 97.24W)	14/2306	1006.8	13/1630	31 (11 m)	37	1.23		1.5	
Port Arthur (PORT2) (29.87N 93.93W)	14/2242	1004.3	14/1530	23 (11 m)	34	2.30		2.3	
Port Mansfield (PMNT2) (26.56N 97.43W)								1.1**	
Rincon del San Jose (RSJT2) (26.80N 97.47W)								1.0**	
Rainbow Bridge (8770520) (29.98N 93.88W)						2.23		2.2	
Sargent (SGNT2) (28.77N 95.62W)	14/0600	993.2	14/0224	44	58	3.68		3.9	
Seadrift (SDRT2) (28.41N 96.71W)	14/0018	1007.1	13/1948	27	39	1.64		1.4	
South Bird Island (IDRT2) (27.48N 97.32W)	14/2218	1007.1	13/1612	28 (4 m)	35	1.4**			
South Padre Island Coast Guard Station (PCGT2) (26.07N 97.17W)						1.29		1.5	
Texas Point (TXPT2) (29.69N 93.84W)	14/2206	1003.3	14/1700	41 (12.5 m)	54	2.49		2.2	
USS Lexington – Corpus Christi (TAQT2) (27.81N 97.39W)						1.63		1.5	
Baffin Bay, Point of Rocks (BABT2) (27.30N 97.42W)	14/2021	1007.4	13/1954	27 (10 m)	35			1.3**	
Moda (MHBT2) (27.82N 97.21W)	14/2318	1007.0	13/2118	25 (10 m)	34				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									

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)				
Dickinson 0.4 SSW (TX-GV-88) (29.45N 95.07W)									8.93
Dickinson 4.4 WSW (TX-GV-82) (29.44N 95.14W)									8.99
League City 0.9 WNW (TX-GV-69) (29.49N 95.12W)									9.11
Beaumont 3.3 SW (TX-JJ-9) (30.05N 94.18W)									8.92
Webster 0.4 NW (TX-HRR-28) (29.54N 95.12W)									8.87
Dickinson 1.4 W (TX-GV-9) (29.44N 95.14W)									8.68
Dickinson 1.7 ENE (TX-GV-76) (29.46N 95.04W)									8.51
Texas City 3.5 W (TX-GV-90) (29.41N 95.02W)									8.39
Alvin 1.6 SW (TX-BRZ-18) (29.42N 95.27W)									8.09
Webster 2.8 NNW (TX-HRR-237) (29.57N 95.13W)									8.07
Galveston 2.6 WSW (TX-GV-65) (29.22N 94.93W)									7.99
Friendswood 2.6 NE (TX-HRR-257) (29.54N 95.17W)									7.83
La Marque 3.9 SE (TX-GV-49) (29.33N 94.94W)									7.75
Anahuac 5.7 N (TX-CHM-11) (29.85N 94.67W)									7.67
WeatherFlow Sites									
Clear Lake Park (XCLP) (29.56N 95.06W)	14/0912	1002.2	14/1718	43 (10 m)	55				
Corpus Christi (XCRP) (27.60N 97.30W)	14/2047	1006.0	13/1530	30 (10 m)	34				
Crab Lake (XCRB) (29.47N 94.62W)	14/1549	1002.2	14/0848	42 (20 m)	49				
Galveston Bay (XGAL) (29.54N 94.91W)	14/1009	999.9	14/0809	44 (5 m)	51				

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)				
Galveston Fishing Pier (XGPR) (29.25N 94.85W)	14/1114	1002.5	14/0553	53 (12 m)	59				
Laguna Shores (XLAG) (27.64N 97.29W)	13/2055	1006.1	13/1723	33 (10 m)	39				
Levee (XLEV) (29.42N 94.89W)	14/1722	1001.5	14/0829	51 (8 m)	61				
Matagorda Bay (XMGB) (28.59N 95.98W)	14/0354	995.0	14/0238	66 (6 m)	82				
Poenisch Park (XPOE) (27.72N 97.34W)	13/2135	1008.1	13/0848	33 (5 m)	38				
Point Comfort (XPTC) (28.69N 96.56W)	14/0051	1003.0	14/0129	27 (10 m)	40				
South Padre Island (XPAD) (26.08N 97.17W)	13/1058	1006.5	13/1258	23 (12 m)	42				
SPIW Park (XSPP) (26.16N 97.18W)	13/1513	1007.9	13/0848	29 (5 m)	39				
Surfside Beach (XSRF)[l] (28.93N 95.29W)	14/0306	1005.5	14/0311	49[l] (8 m)	60[l]				
Texas City (XTEX) (29.37N 94.95W)	14/1616	1002.0	14/0722	42 (20 m)	53				
Wildcat (XWLD) (27.87N 97.32W)	13/2130	1008.0	13/0648	29 (5 m)	34				
Jefferson Count Drainage District 6									
Washington Blvd. @ Caldwood Cut (2200) (30.06N 94.16W)									8.06
Boondocks @ D-700 Taylors Bayou (6400) (29.85N 94.23W)									8.04
Tyrrell Park Detention @ Phelps Rd. (2320) (30.02N 94.16W)									9.23
State Highway 365 @ Ditch 600 (5400) (29.94N 94.33W)									8.12
South 11th Street detention Pond (2420) (30.05N 94.14W)									8.02
East Lane @ Ditch 200 – Willow March Bayou (3500) (30.06N 94.21W)									7.96
Lawhon Road at Green Pond Road (6100) (30.00N 94.30W)									7.93
South Pine Island Road @ Ditch 607 (5300) (30.03N 94.26W)									7.83
Mayhaw Bayou @ Englin Road (7200) (29.79N 94.33W)									7.74

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)				
M.H.M.R South 8th Street @ Ditch 110 (2400) (30.06N 94.12W)									7.61
T.P.W.D. Boat Ramp in J.D. Murphree @ Ditch 500 (6300) (29.88N 94.05W)									7.57
Landis Drive @ Ditch 202B (2700) (30.07N 94.20W)									7.56
Harris County Flood Warning System (HCFWS) Sites									
Clear Creek at I-45 /Friendswood 2 E (110) (29.50N 95.16W)									7.96
National Weather Service / Harris County Flood Control District High Water Marks									
Mouth of Brays Bayou at Houston Ship Channel (29.73N 95.28W)							8.3*	5.8*	
Jamaica Beach (29.19N 94.96W)							7.4	5.4	
Treasure Island (29.08N 95.13W)							7.2	5.2	
Sylvan Beach (29.65N 95.01W)							7.1	5.1	
Stewart Beach – Galveston Island (29.31N 94.77W)							6.76	4.8	
Matagorda Beach (28.61N 95.96W)							6.2	4.7	
Matagorda (28.63N 95.97W)							7.16	4.6	
Nassau Bay (29.54N 95.09W)							6.7	4.5	
Lynchburg Ferry (29.76N 95.08W)							7.0	4.5*	
Matagorda (28.65N 95.96W)							7.4	4.4	
I-10 at San Jacinto River (29.80N 95.07W)							6.9	4.4*	
Kemah Boardwalk (29.54N 95.02W)							6.3	4.1	
Seabrook (29.56N 95.02W)							6.1	4.1	
Beach City (29.66N 94.92W)							6.3	3.8	
San Leon (29.48N 94.92W)							6.7	3.7	

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)				
Matagorda Beach (28.60N 95.98W)							5.15	3.7	
Beach City – Centerpoint Energy Facility (29.76N 94.82W)							6.15	3.7	
Surfside Beach (28.97N 95.27W)							5.6	3.6	
Shoreacres (29.62N 95.02W)							6.0	3.5	
Baytown – Bayland Park (29.71N 94.99W)							6.0	3.5	
Sargent (28.77N 95.63W)							5.1	3.1	
Surfside (28.95N 95.29W)							6.09	3.1	
Matagorda (28.68N 95.96W)							4.9	2.9	
Follet's Island (29.05N 95.16W)							4.75	2.8	
Tiki Island (29.30N 94.91W)							4.98	2.5	
Sargent Beach (28.77N 95.62W)							5.4	2.4	
Quintana Beach (28.92N 95.34W)							6.2	2.2	
Texas City Dike (29.39N 94.89W)							4.7	1.5	
USGS Stream Gauges									
Old Brazos River near Freeport (28.95N 95.34W)						7.10 (NGVD29)	5.5		
West Fork Double Bayou near Anahuac (29.68N 94.67W)						4.80	3.5		
Colorado River near Wadsworth (28.77N 96.00W)						4.07	3.3		
Other Sites									
Sargent 1 ENE (SECT2) (28.84N 95.66W)									8.69
1 W Port O'Connor (28.44N 96.41W)									7.11
6 SE Corpus Christi (27.71N 97.43W)									3.85
Hannibal Point (28.08N 97.10W)			13/2124	37	42				
Port O'Connor Waterway (28.44N 96.41W)	14/0040	1000.7	14/0000	44	54				
Louisiana									
ICAO Sites									
Lake Charles Regional AP (KLCH) (30.13N 93.23W)	15/0853	1005.9	14/2253	26 (2 min, 10 m)	36				

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)				
Sulphur/Southland Field AP (KUXL) (30.13N 93.38W)	15/0815	1005.4	14/1435	28 (2 min, 10 m)	36				
New Orleans International AP (KMSY) (30.00N 90.28W)									8.24
COOP Sites									
Bunkie (BNKL1) (30.96N 92.18W)									14.17
Lake Charles 7 NW (LCRL1) (30.30N 93.27W)									13.69
Ruby 3 W (RRBL1) (31.18N 92.30W)									9.50
Red River Lock #2 (167732) (31.19N 92.29W)									9.48
Beaver Fire Tower (160617) (30.79N 92.50W)									9.06
Marksville (MKVL1) (31.13N 92.07W)									8.78
Oberlin Fire Tower (OBEL1) (30.60N 92.77W)									8.34
HADS Sites									
Hammond 5 W (NRBL1) (30.50N 90.55W)									12.51
Hammond 5 E (ROBL1) (30.51N 90.36W)									12.43
Mittie (MTTL1) (30.70N 92.90W)									12.42
Basile 2W (BSLL1) (30.48N 92.63W)									9.44
Amite (AMIL1) (30.73N 90.48W)									9.26
Darlington 4 WNW (DARL1) (30.89N 90.84W)									8.16
NOAA Advanced Hydrologic Prediction Service River Gauges									
Mermentau (MRML1) (30.18N 92.58W)									14.51
Lafayette-Vermilion River @ Surrey St. (VLSL1) (30.22N 92.00W)									13.04
Glenmora 5 WNW (GLML1) (31.00N 92.67W)									12.08
Folsom 4 SW (FLSL1) (30.62N 90.25W)									12.06
Denham Springs 3 SW (DENL1) (30.46N 90.99W)									11.34
Holden (HOLL1) (30.50N 90.68W)									10.66
Montpelier (MONL1) (30.69N 90.54W)									10.27

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)				
Magnolia-Amite R. (MAGL1) (30.53N 90.98W)									10.24
Millerville (NBWL1) (30.42N 91.09W)									8.93
Inniswold 1 NW (WCEL1) (30.40N 91.10W)									8.89
Port Vincent/Amite River (PVLL1) (30.33N 90.85W)									8.45
Kentwood (KENL1) (30.93N 90.48W)									8.40
Morgan City/Lower Atchafalaya R2 (MCGL1) (29.70N 91.21W)									7.94
Melville (MLVL1) (30.69N 91.74W)									7.73
Alexandria (AEXL1) (31.32N 92.45W)									7.71
CoCoRaHS Sites									
Hammond 4.9 WNW (LA-TG-18) (30.53N 90.54W)									17.29
St. Bernard 2.7 E (LA-SB-2) (29.87N 89.81W)									13.78
Bunkie 0.3 WSW (LA-AV-1) (30.95N 92.19W)									13.64
Gonzales 4.5 S (LA-AS-11) (30.15N 90.93W)									11.68
LSU (LA-EB-33) (30.41N 91.18W)									10.73
Baton Rouge 3.0 SSE (LA-EB-53) (30.41N 91.11W)									9.73
Baton Rouge 4.0 SSE (LA-EB-60) (30.40N 91.09W)									9.09
Baton Rouge 3.5 E (LA-EB-14) (30.44N 91.07W)									9.01
Westwego 2.4 ENE (LA-OR-13) (29.92N 91.11W)									8.86
New Orleans 3.8 WSW (LA-OR-14) (29.94N 90.13W)									8.52
Baton Rouge 2.5 E (LA-EB-27) (30.45N 91.08W)									8.09
FSA Marksville 1.0 W (LA-AV-5) (31.13N 92.08W)									7.80
NOS Sites									

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)				
Calcasieu Pass (CAPL1) (29.77N 93.34W)	15/0006	1003.4	14/1518	37 (12 m)	43	2.89		1.9	
North of Eugene Island (EINL1) (29.37N 91.38W)	15/2148	1006.0	15/0654	27 (4 m)	34	2.25		2.3	
LAWMA, Amerada Pass (AMRL1) (29.45N 91.34W)						2.54		2.7	
Shell Beach (SHBL1) (29.87N 89.67W)						2.09		2.6	
Freshwater Canal Locks (FRWL1) (29.55N 92.31W)						3.41		2.5	
New Canal Station (NWCL1) (30.03N 90.11W)						1.80		2.2	
Lake Charles (LCLL1) (30.22N 93.22W)						2.69		1.9	
Pilot's Station East (PSTL1) (28.93N 89.41W)						1.43		1.9	
Bulk Terminal (BKTL1) (30.19N 93.30W)						2.86		1.8	
Grand Isle (GISL1) (29.26N 89.96W)						1.02		1.6	
West Bank 1, Bayou Gauche (BYGL1) (29.79N 90.42W)								1.4*	
Berwick (TESL1) (29.67N 91.24W)						1.93		1.1	
Pilottown (PILL1) (29.18N 89.26W)						0.63		1.0	
Mississippi									
ICAO Sites									
Keesler AFB (KBIX) (30.40N 91.10W)									8.89
McComb AP (KMCB) (31.18N 90.47W)									7.17
Pascagoula Lott Int. AP (KPQL) (30.46N 88.53W)									7.05
NOAA Advanced Hydrologic Prediction Service River Gauges									
Orange Grove 3 NNE (ORAM6) (30.46N 88.45W)									13.40
Graham Ferry/Pascagoula R. (PGFM6) (30.61N 88.64W)									11.94
Leakesville (LEKM6) (31.15N 88.56W)									8.59
Tylertown 9 NW (TYTM6) (31.18N 90.28W)									7.33
COOP Sites									

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)				
Biloxi (BLXM6) (30.39N 89.00W)									11.13
CoCoRaHS Sites									
Biloxi 13.1 NNW (MS-HR-24) (30.57N 89.05W)									8.37
Hattiesburg 3.7 WNW (MS-LM-9) (31.33N 89.36W)									7.95
Moss Point 1.2 NNW (MS-JC-27) (30.44N 88.53W)									7.59
Liberty 6.4 ENE (MS-AM-1) (31.20N 90.70W)									7.36
NOS Sites									
Bay Waveland Yacht Club (WYCM6) (30.33N 89.33W)						2.67		3.3	
Alabama									
NOAA Advanced Hydrologic Prediction Service River Gauges									
Wright (WRTA1) (34.96N 87.95W)									8.30
Athens (AHNA1) (34.79N 86.97W)									7.45
Huntsville (CNTA1) (34.73N 86.59W)									7.16
Semmes 5 SW (BCDA1) (30.72N 88.30W)									7.06
COOP Sites									
Dora (12350) (33.75N 87.06W)									8.62
Dauphin Island #2 (DAUA1) (30.25N 88.08W)									8.46
Athens (ATHA1) (34.78N 86.95W)									8.45
Wetumpka (WETA1) (32.59N 86.17W)									7.23
Holly Tree (13900) (34.80N 86.28W)									7.07
CoCoRaHS Sites									
Elberta 3.9 S (AL-WO-96) (30.51N 87.18W)									10.40
Foley 2.0 SSW (AL-WO-31) (30.38N 87.70W)									10.06
Cloverdale 6.6 WSW (AL-LD-9) (34.91N 87.88W)									8.85
Mobile 5.0 WNW (AL-MB-60) (30.74N 88.18W)									8.82

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)				
Athens 1.5 SE (AL-LS-23) (34.79N 86.95W)									8.71
Dauphin Island 4.8 E (AL-MB-92) (30.25N 88.09W)									8.31
Hazel Green 1.2 NW (AL-MD-06) (34.94N 86.58W)									8.27 [I]
Harvest 3.9 SE (AL-MD-85) (34.82N 86.70W)									8.06
Fairhope 3.7 NNW (AL-BW-13) (30.57N 87.90W)									8.03
Wetumpka 5.4 WNW (AL-EL-22) (32.57N 86.29W)									7.97
Alexander City 3.1 NNE (AL-TP-7) (32.99N 85.95W)									7.87
Athens 2.7 E (AL-LS-19) (34.79N 86.91W)									7.85
Gulf Shores 3.1 N (AL-BW-66) (30.31N 87.71W)									7.85
Alexander City 10.0 SW (AL-CS-3) (32.82N 86.05W)									7.70
Wetumpka 9.9 NNE (AL-EL-18) (32.68N 86.14W)									7.67
Daphne 1.2 NNW (AL-BW-3) (30.64N 87.91W)									7.54
Wilmer 7.9 SE (AL-MB-24) (30.74N 88.27W)									7.52
Mobile 4.5 WSW (AL-MB-73) (30.66N 88.16W)									7.44
Foley 4.9 SE (AL-BW-95) (30.35N 87.63W)									7.25
Woodville 8 NE (AL-JC-12) (34.73N 86.21W)									7.17
Mobile 1.2 WSW (AL-MB-49) (30.67N 88.11W)									7.08
NASA Rain Network									
Huntsville (MASA1) (34.77N 86.59W)									7.25

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)				
Florida									
COOP Sites									
Pensacola 7 NNE (86999) (30.53N 87.20W)									10.89
Pensacola (PSAF1) (30.53N 87.20W)									10.67
NOAA Advanced Hydrologic Prediction Service River Gauges									
Milton 7 ESE (MLYF1) (30.57N 86.92W)									8.12
CoCoRaHS Sites									
Pensacola 6.4 N (FL-ES-54) (30.54N 87.21W)									12.66
Pensacola 18.9 WSW (FL-ES-24) (30.31N 87.47W)									12.15
Pensacola 13.5 WNW (FL-ES-35) (30.53N 87.39W)									11.56
Pensacola 2.4 SW (FL-ES-48) (30.42N 87.22W)									10.43
Destin 1.2 NW (FL-OK-33) (30.42N 87.22W)									9.78
Panama City 1.9 SE (FL-BY-24) (30.15N 85.65W)									9.27
Gonzalez 2.1 E (FL-ES-15) (30.57N 87.25W)									8.30
Navarre 6.2 E (FL-SR-21) (30.41N 86.81W)									8.11
Niceville 2.1 SE (FL-OK-37) (30.51N 86.47W)									7.83
Valparaiso 1.4 N (FL-OK-42) (30.51N 86.50W)									7.30
Miramar Beach 9.5 ESE (FL-WT-3) (30.35N 86.20W)									7.27 [I]
Eglin AFB 5.6 NE (FL-OK-2) (30.52N 86.49W)									7.08

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)				
Other Sites									
Choctaw Naval Outlying Field (53848) (30.51N 86.96W)									7.37
Georgia									
COOP Sites									
Eastman 1 W (92966) (32.20N 83.21W)									9.74
Nahunta 6 NE (92619) (31.27N 81.92W)									7.30
Hawkinsville (HAWG1) (32.28N 83.47W)									5.17
NOAA Advanced Hydrologic Prediction Service River Gauges									
Atkinson 1 W (ATKG1) (31.22N 81.87W)									6.55
CoCoRaHS Sites									
Chauncey 2.6 SW (GA-DG-4) (32.08N 83.09W)									7.24
Thomasville 5.1 ESE (GA-TH-4) (30.82N 83.90W)									5.45
Macon 2.2 NE (GA-BB-22) (32.86N 83.63W)									5.27
Rocky Ford 4.2 N (GA-SV-8) (32.72N 81.83W)									5.21
Other Sites									
Nahunta 3 E (NAHG1) (31.22N 81.93W)									7.30
Tennessee									
COOP Sites									
Shelbyville Water Department (408246) (35.49N 86.48W)									10.06
Tullahoma 4 NE (409157) (35.43N 86.20W)									9.88
Mousetail Landing State Park (406308) (35.66N 88.01W)									8.33

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)				
Fayetteville Water Plant (FYVT1) (35.13N 86.54W)									7.92
Columbia 3 WNW (401957) (35.64N 87.09W)									7.01
HADS Sites									
Normandy 2 NE (NDPT1) (35.47N 86.25W)									8.96
Winchester 13 SW (SLMT1) (35.09N 86.25W)									8.33
Morrison (MRST1) (35.62N 85.90W)									7.71
CoCoRaHS Sites									
Pikeville 8.2 WSW (TN-BL-21) (35.55N 85.33W)									11.20
Pikeville 7.5 SW (TN-BL-2) (35.54N 85.30W)									10.14
Fayetteville 0.6 SSW (TN-LC-9) (35.14N 86.57W)									8.40
Manchester 9.2 NNW (TN-CF-35) (35.59N 86.15W)									7.90
Manchester 2.6 WNW (TN-CF-14) (35.48N 86.13W)									7.57
Shelbyville 5.7 SSE (TN-BF-37) (35.41N 86.42W)									7.17 [I]
Mexico									
Playa Bagdad (25.82N 97.15W)			13/0945	30	37				
Offshore									
NOAA Buoys									
35 NM NE Pt. Mansfield, TX (42020) (26.96N 96.70W)	13/1820	1005.7	13/1430	37 (10 min, 4 m)	49				
60 NM S Freeport, TX (42019) (27.91N 95.35W)	13/2310	1002.9	13/2024	43 (1 min, 4 m)	52				
20 NM E Galveston, TX (42035) (29.24N 94.41W)	14/2020	1004.1	14/0809	43 (1 min, 4 m)	49				

[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). Storm tide is water height above Mean Lower Low Water (MLLW) for NOS stations in Puerto Rico, the U.S. Virgin Islands, and Barbados.
[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.
[I] Incomplete
* Water levels likely had a significant freshwater contribution from rainfall.
** Station is located in a nontidal area, and the value is referenced above Mean Sea Level (MSL).

Table 4. 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%)	66	78
Medium (40%-60%)	48	60
High (>60%)	30	48

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Nicholas, 12–15 September 2021. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	30.6	39.9	57.7	77.7	100.3	108.8		
OCD5	52.3	110.3	159.5	185.0	224.3	363.2		
Forecasts	11	9	7	5	3	1		
OFCL (2016-20)	23.9	36.3	49.1	63.9	79.0	94.1	128.1	169.7
OCD5 (2016-20)	45.1	97.2	157.2	216.7	271.1	325.4	414.4	490.0

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Nicholas, 12–15 September 2021. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement. Due to their limited sample size compared to the other models, track models CTCI, CMCI, and EGRI were not included in this comparison.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	31.0	39.9	57.7	77.7	100.3	108.8		
OCD5	55.5	110.3	159.5	185.0	224.3	363.2		
TABS	77.2	143.0	196.9	237.5	307.6	338.5		
TABM	48.7	68.0	84.6	102.6	126.1	162.7		
TABD	47.8	84.1	124.9	160.7	176.2	162.8		
TVDG	**30.7**	42.8	69.7	88.3	106.9	**93.2**		
TVCA	31.0	44.0	71.6	92.7	113.6	108.8		
GFEX	31.8	43.4	67.2	86.1	111.7	**89.0**		
TVCX	31.4	44.3	73.1	89.9	117.1	109.0		
FSSE	**29.3**	**38.5**	64.5	95.9	121.5	115.2		
HCCA	**30.5**	**37.8**	60.9	80.7	109.9	**98.6**		
AEMI	**29.7**	45.2	68.3	90.1	127.8	156.7		
NVGI	**25.9**	**32.9**	**53.2**	81.9	107.3	121.1		
EMXI	36.5	60.5	96.1	116.9	187.0	151.5		
HWFI	37.6	53.0	71.9	94.8	107.3	116.4		
HMNI	**30.9**	47.6	71.4	88.4	**97.9**	**30.4**		
GFSI	**27.8**	**36.1**	**55.5**	100.7	**92.8**	**40.4**		
Forecasts	10	9	7	5	3	1		

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Nicholas, 12–15 September 2021. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	**3.2**	**5.6**	**5.0**	**2.0**	**5.0**	**5.0**		
OCD5	6.2	7.9	9.3	7.8	12.3	35.0		
Forecasts	11	9	7	5	3	1	0	0
OFCL (2016-20)	5.4	8.0	9.6	10.9	11.5	12.1	13.3	14.5
OCD5 (2016-20)	7.0	11.0	14.3	16.8	18.3	19.7	21.7	23.0

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Nicholas, 12–15 September 2021. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 6a due to the homogeneity requirement. Due to their limited sample size compared to the other models, intensity models CTCI, CMCI, and EGRI were not included in this comparison.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	3.5	5.6	5.0	2.0	5.0	5.0		
OCD5	6.5	7.9	9.3	7.8	12.3	35.0		
IVDR	7.2	7.6	7.9	2.4	**1.7**	**2.0**		
IVCN	7.2	7.8	8.4	**1.4**	**2.7**	**3.0**		
ICON	7.4	8.7	8.4	**1.4**	**3.0**	**3.0**		
LGEM	7.7	8.9	10.9	3.2	**4.0**	6.0		
DSHP	7.4	8.7	9.6	2.4	5.3	7.0		
FSSE	6.9	6.2	6.4	4.2	6.3	8.0		
HCCA	6.7	6.4	7.7	4.2	**4.0**	**4.0**		
EMXI	10.0	14.0	12.3	4.0	**2.7**	**1.0**		
HWFI	7.0	8.1	6.3	5.8	**1.0**	**2.0**		
HMNI	9.0	9.4	9.4	2.6	**2.3**	**1.0**		
GFSI	8.8	9.8	7.6	4.0	**4.3**	**1.0**		
Forecasts	10	9	7	5	3	1	0	0

Table 7. Storm surge watch and warning summary for Hurricane Nicholas, 12–15 September 2021.

Date/Time (UTC)	Action	Location
12 / 1500	Storm Surge Watch issued	Mouth of the Rio Grande to High Island TX
12 / 2100	Storm Surge Warning issued	Port Aransas to San Luis Pass TX, including Aransas Bay, San Antonio Bay, and Matagorda Bay
13 / 0300	Storm Surge Watch extended	East of High Island TX to Rutherford Beach LA, including Galveston Bay
13 / 1500	Storm Surge Warning extended	San Luis Pass TX to Sabine Pass, including Galveston Bay
13 / 1500	Storm Surge Watch discontinued	Mouth of the Rio Grande to Baffin Bay TX
13 / 2100	Storm Surge Watch discontinued	Baffin Bay to Port Aransas TX, including Corpus Christi Bay
14 / 0600	Storm Surge Warning discontinued	Port Aransas to Port O’Connor TX, including Aransas Bay and San Antonio Bay
14 / 0900	Storm Surge Warning discontinued	Port O’Connor to Sargent TX, including Matagorda Bay
14 / 1200	Storm Surge Warning discontinued	Sargent to San Luis Pass TX
14 / 1500	Storm Surge Warning discontinued	South of Port Bolivar TX
14 / 1500	Storm Surge Watch discontinued	East of Cameron LA
14 / 1800	Storm Surge Warning discontinued	West of High Island TX, including Galveston Bay
14 / 2100	Storm Surge Warning discontinued	All
14 / 2100	Storm Surge Watch discontinued	All

Table 8. Wind watch and warning summary for Hurricane Nicholas, 12–15 September 2021.

Date/Time (UTC)	Action	Location
12 / 1500	Tropical Storm Watch issued	Port Aransas to High Island
12 / 1500	Tropical Storm Warning issued	Barra el Mezquital to TX/MEX border
12 / 1500	Tropical Storm Warning issued	TX/MEX border to Port Aransas
12 / 2100	Tropical Storm Warning modified to	TX/MEX border to Freeport
12 / 2100	Hurricane Watch issued	Port Aransas to Sargent
13 / 0300	Tropical Storm Watch modified to	High Island to Sabine Pass
13 / 0300	Tropical Storm Warning modified to	TX/MEX border to High Island
13 / 0300	Hurricane Watch modified to	Port Aransas to Freeport
13 / 1500	Tropical Storm Watch discontinued	All
13 / 1500	Tropical Storm Warning discontinued	Barra el Mezquital to TX/MEX border
13 / 1500	Tropical Storm Warning modified to	TX/MEX border to Sabine Pass
13 / 1500	Hurricane Watch modified to	Port Aransas to San Luis Pass
13 / 2100	Tropical Storm Warning modified to	Baffin Bay to Sabine Pass
14 / 0300	Tropical Storm Warning modified to	Port Aransas to Port O’Connor
14 / 0300	Hurricane Watch modified to	Freeport to San Luis Pass
14 / 0300	Hurricane Warning issued	Port O'Connor to Freeport
14 / 0900	Tropical Storm Warning discontinued	Port Aransas to Port O'Connor

Date/Time (UTC)	Action	Location
14 / 0900	Tropical Storm Warning modified to	Matagorda to Freeport
14 / 0900	Tropical Storm Warning issued	Sabine Pass to Cameron, Louisiana
14 / 0900	Hurricane Watch discontinued	All
14 / 0900	Hurricane Warning discontinued	All
14 / 1200	Tropical Storm Warning modified to	San Luis Pass to Cameron
14 / 1500	Tropical Storm Warning modified to	High Island to Cameron
15 / 0000	Tropical Storm Warning discontinued	All

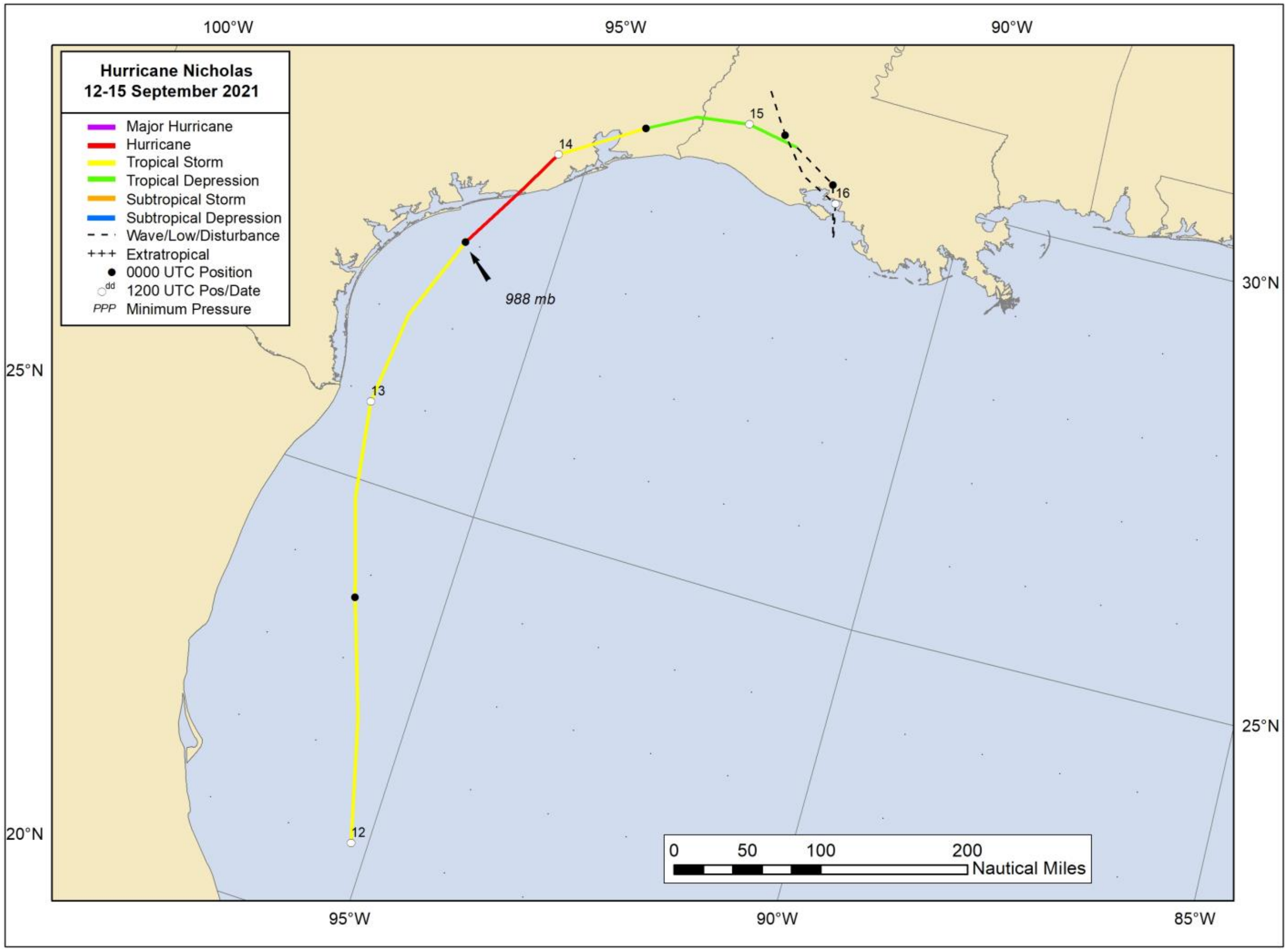

Figure 1. Best track positions for Hurricane Nicholas, 12–15 September 2021. The track over the United States is partially based on analyses from the NOAA Weather Prediction Center.

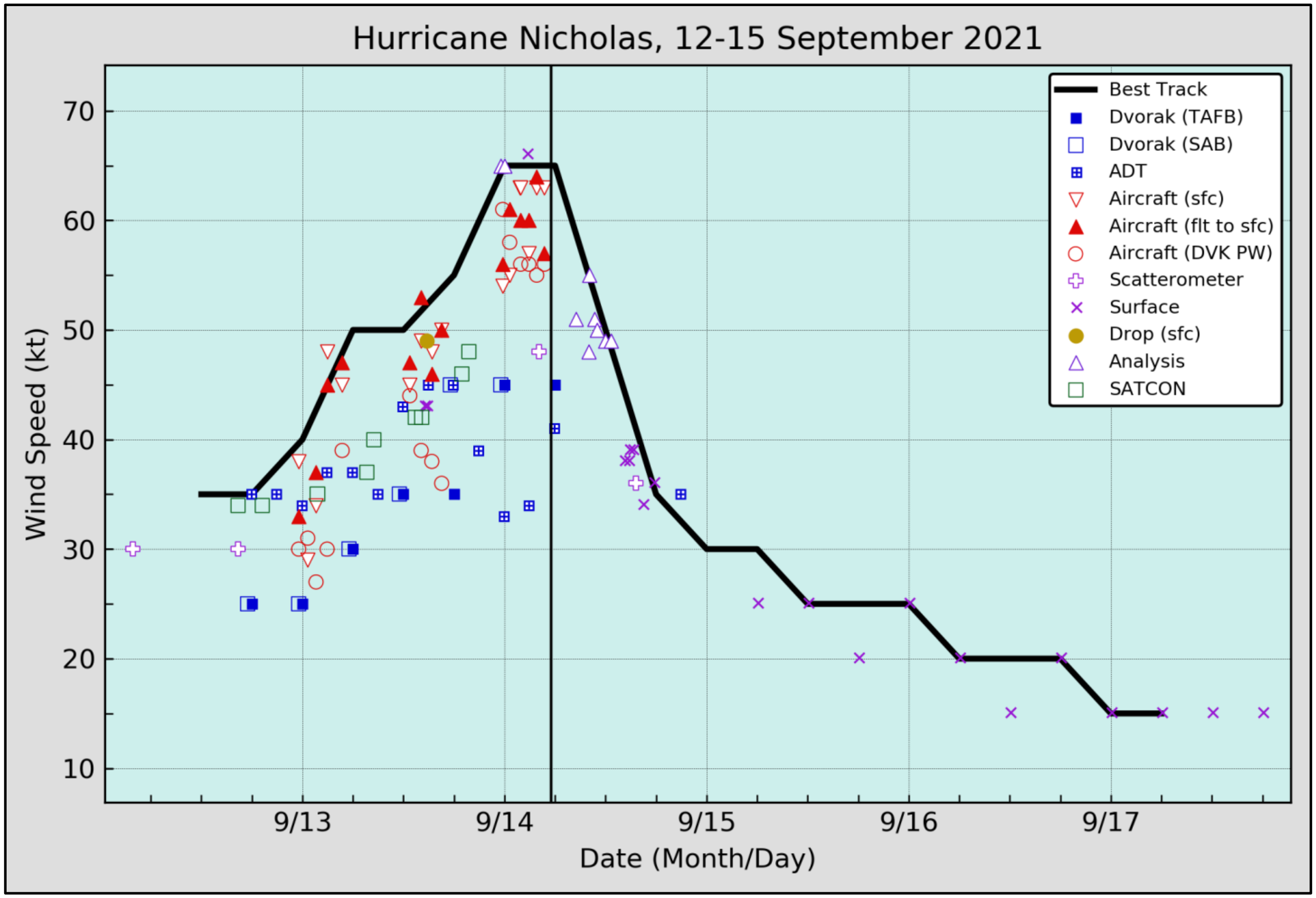

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Nicholas, 12–15 September 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. 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. Dashed vertical lines correspond to 0000 UTC. The solid vertical line corresponds with landfall.

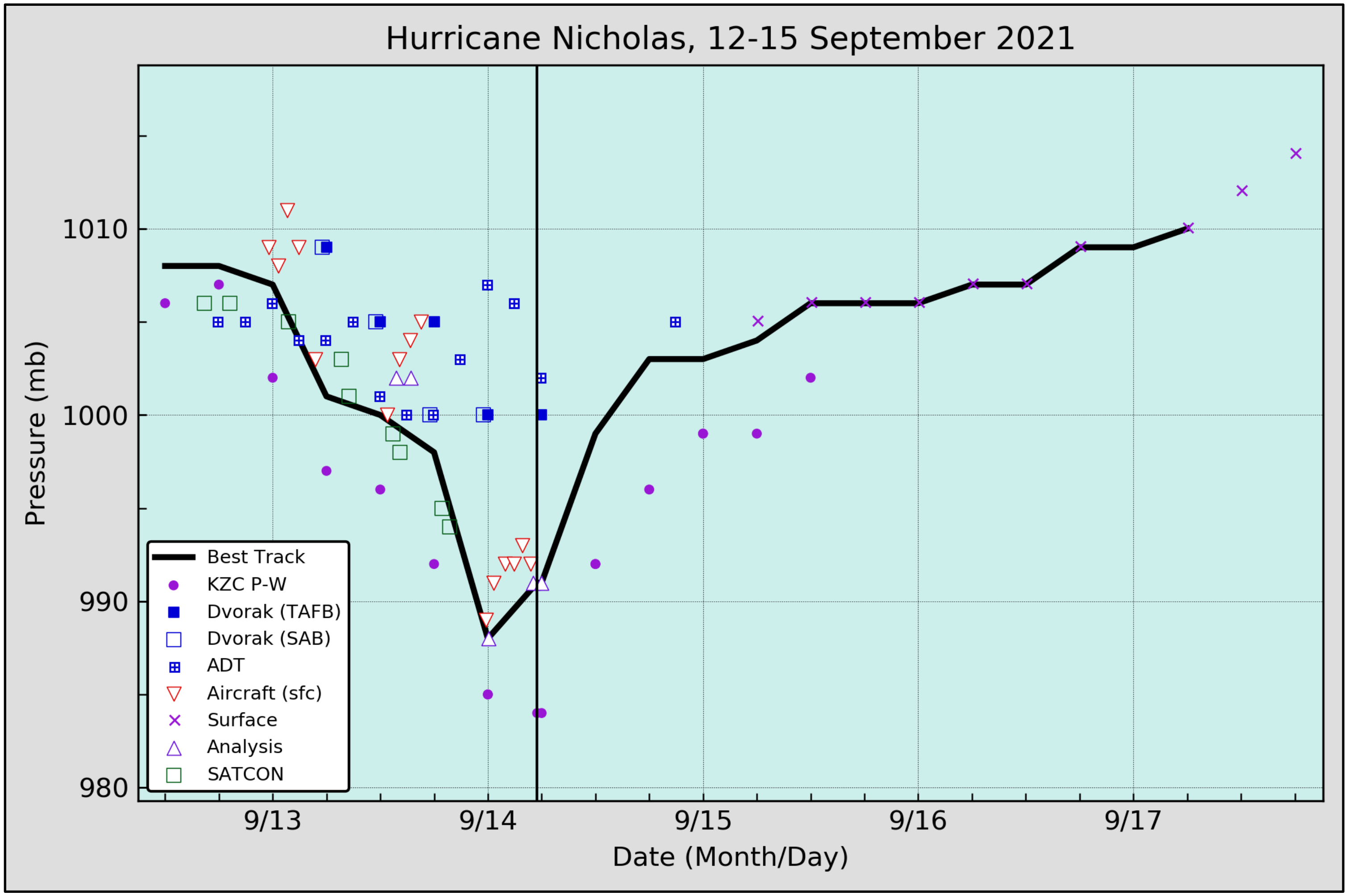

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Nicholas, 12–15 September 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC. The solid vertical line corresponds with landfall.

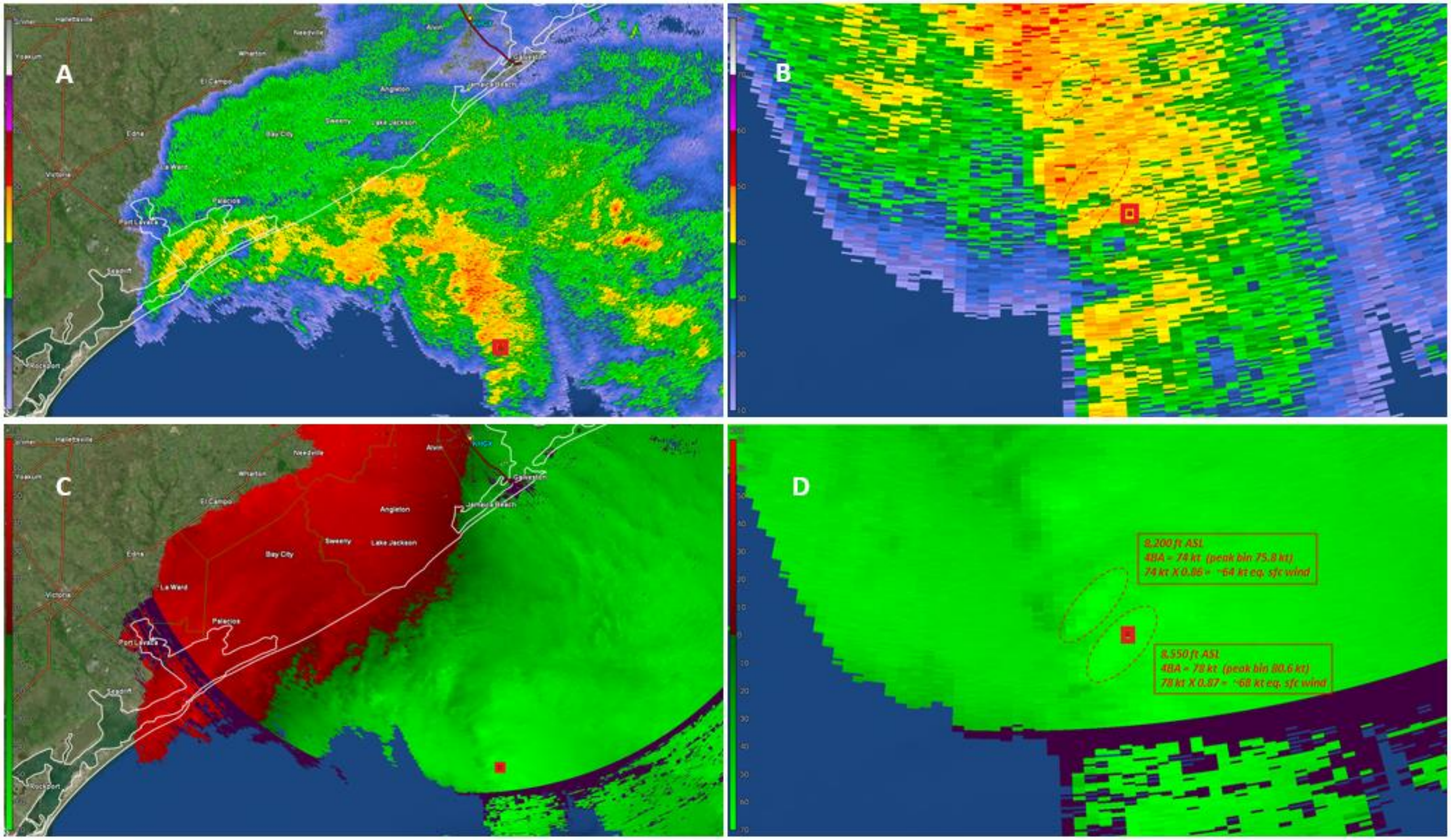

Figure 4. Houston, Texas (KHGX) WSR-88D Doppler radar view of Nicholas at 2332 UTC 13 September, about 6 h prior to landfall. Antenna elevation was 0.5° — (a) Reflectivity (dBZ), (b) Reflectivity zoomed-in (c) Doppler velocity (kt), and (d) zoomed-in Doppler velocity and radar analysis.

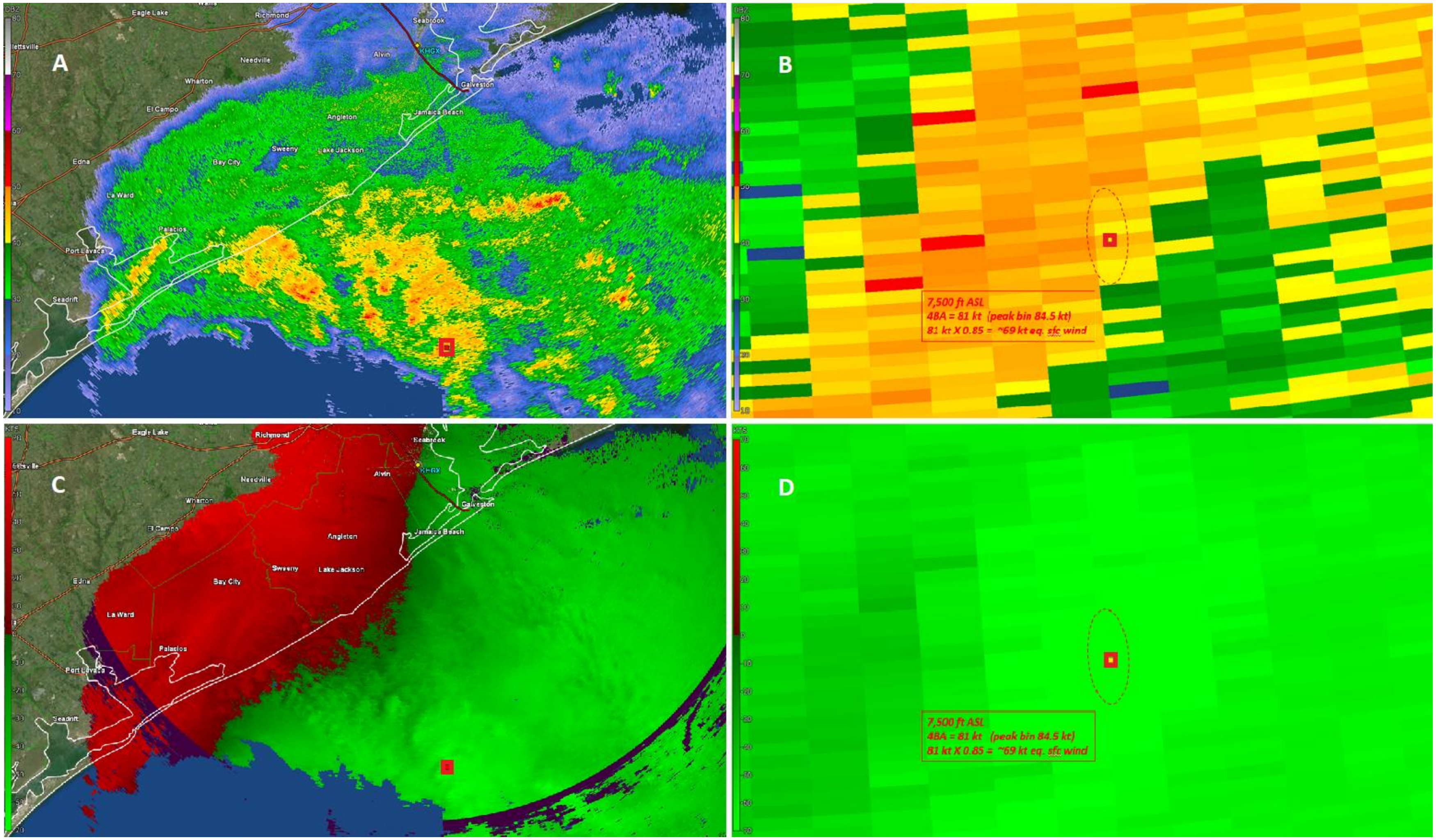

Figure 5. Houston, Texas (KHGX) WSR-88D Doppler radar view of Nicholas at 0001 UTC 14 September. Antenna elevation was 0.5° — (a) Reflectivity (dBZ), (b) Reflectivity zoomed-in (c) Doppler velocity (kt), and (d) zoomed-in Doppler velocity and radar analysis

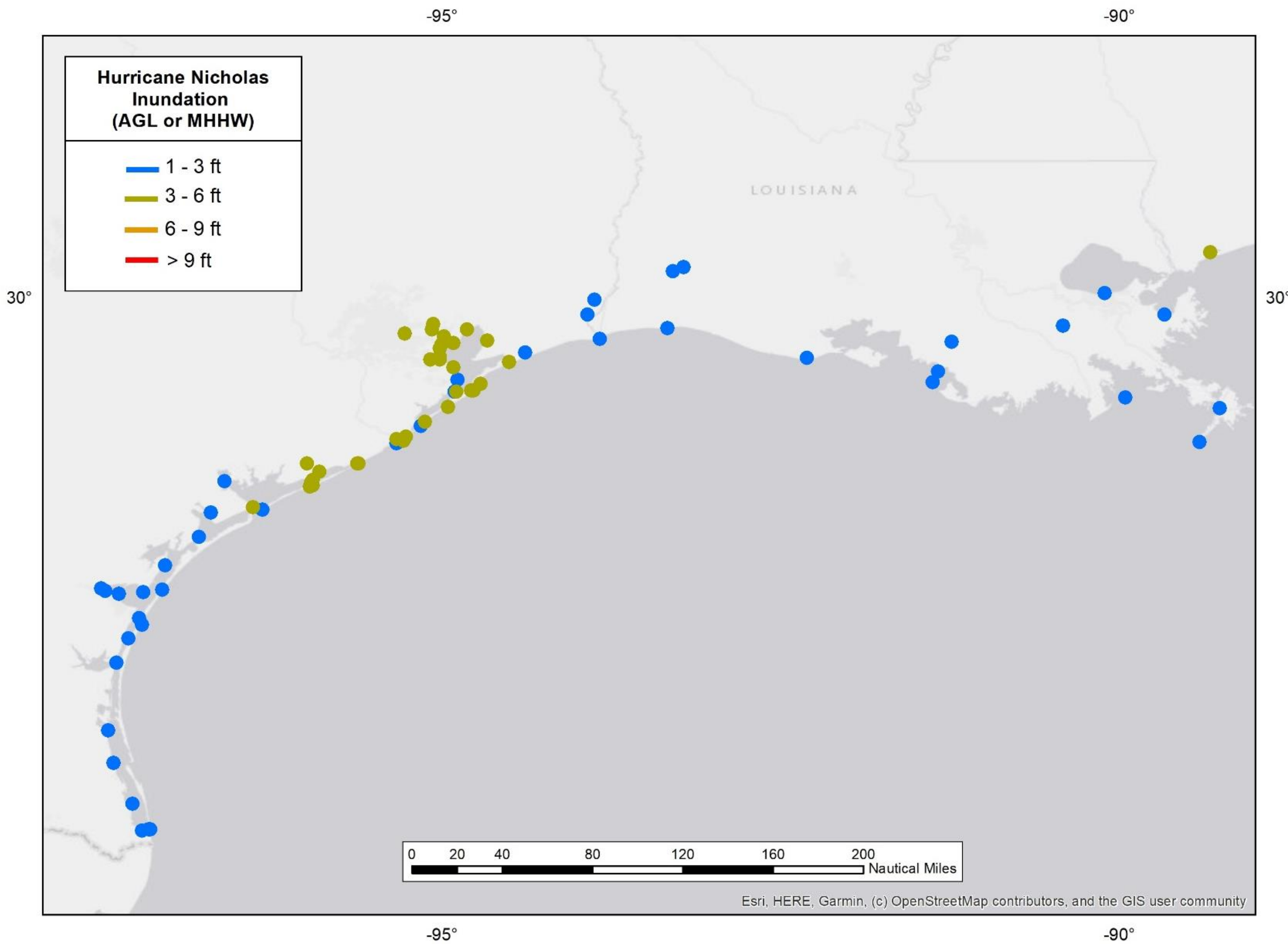

Figure 6. Maximum water levels measured from tide and stream gauges and surveyed high water marks from Hurricane Nicholas. Depending on the data type, water levels are referenced as feet above ground level (AGL), or Mean Higher High Water (MHHW) / Mean Sea Level (MSL), which are used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline.

Figure 7. Storm surge flooding in Treasure Island, Texas. Photo credit: UPI.com

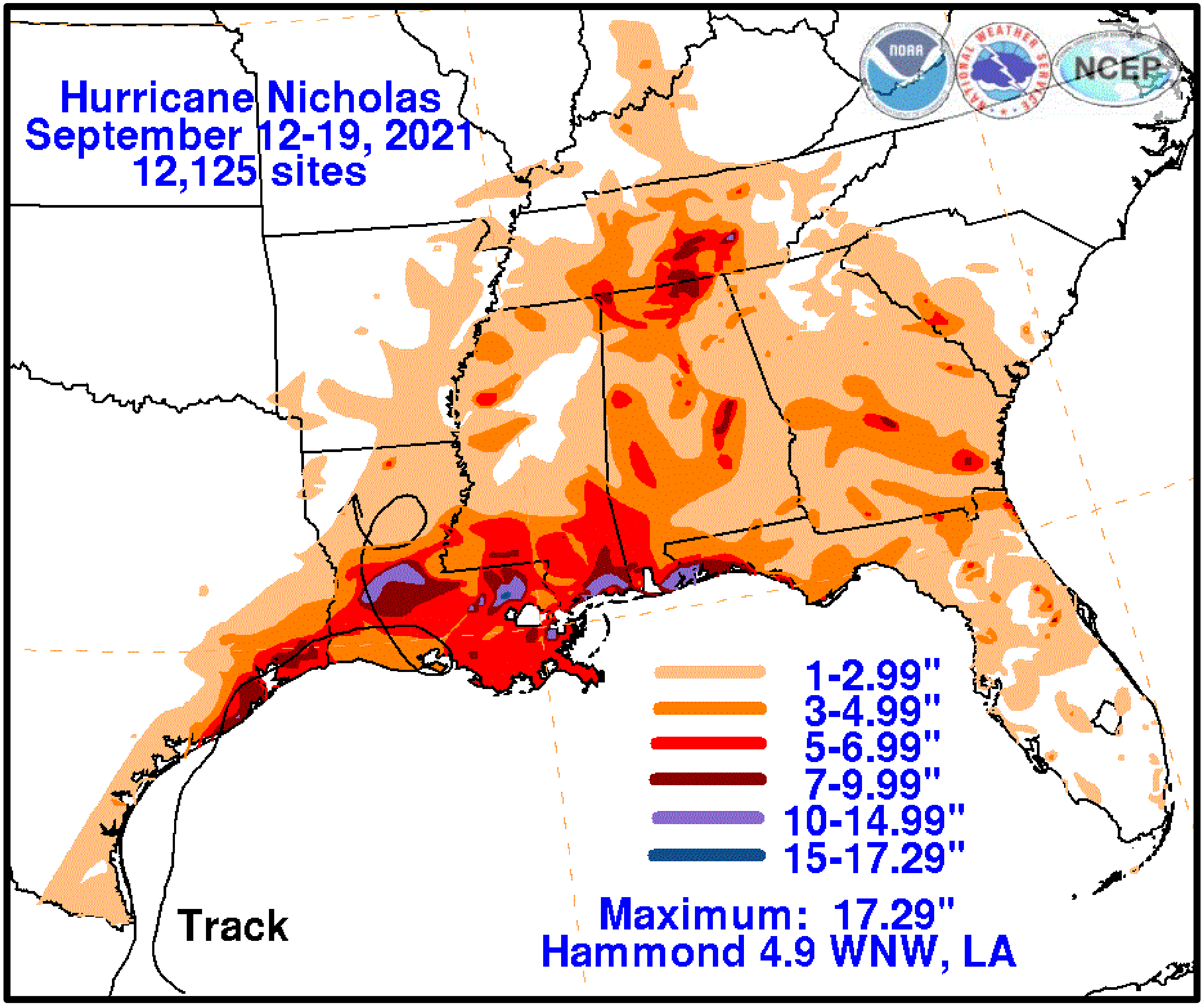

Figure 8. Hurricane Nicholas total rainfall map (inches) over the U.S. compiled from 12125 rain gauges from 12–19 September 2021. Image courtesy of the NOAA Weather Prediction Center.

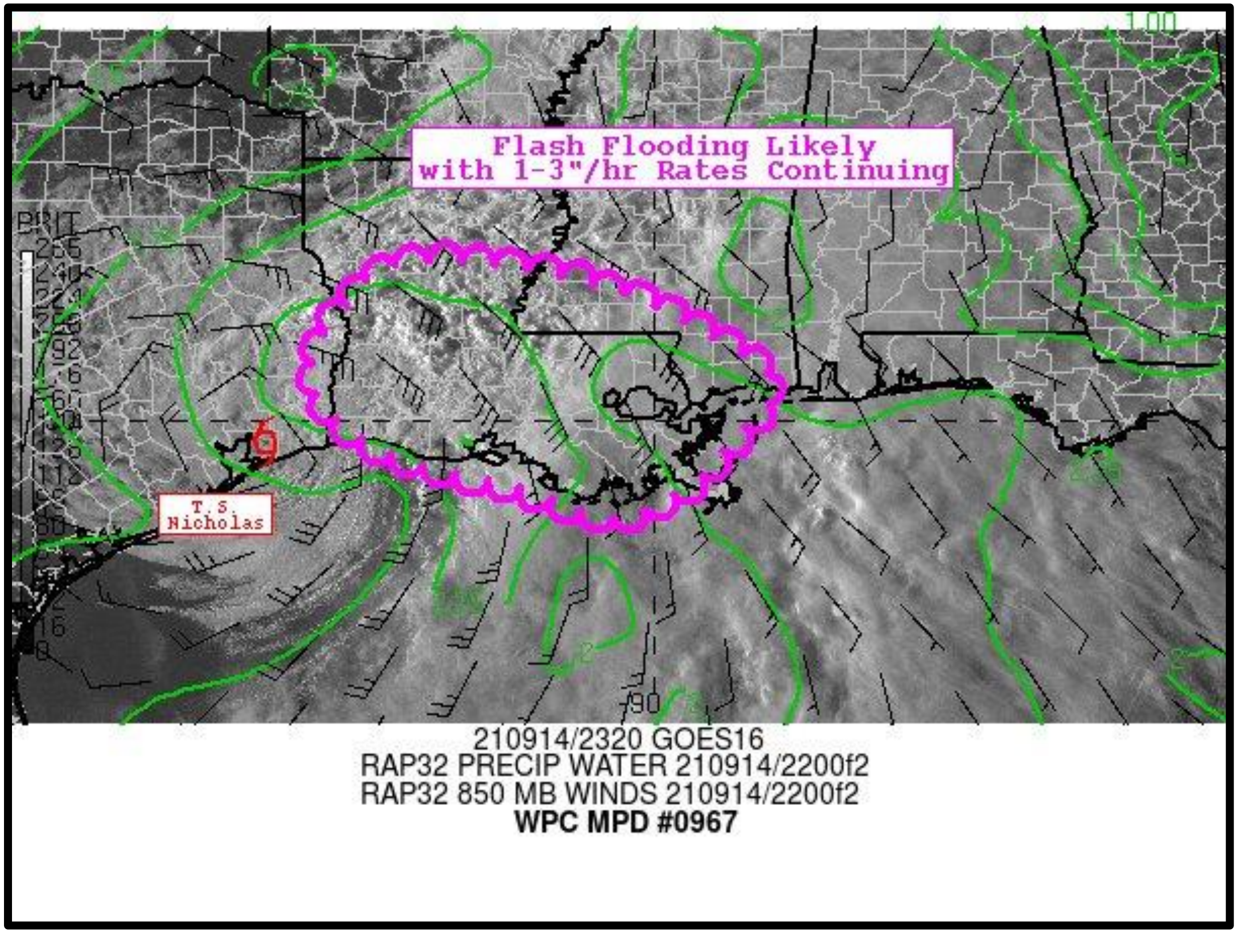

Figure 9. Mesoscale setup for the heavy rainfall event over southern Louisiana. Image courtesy of WPC.

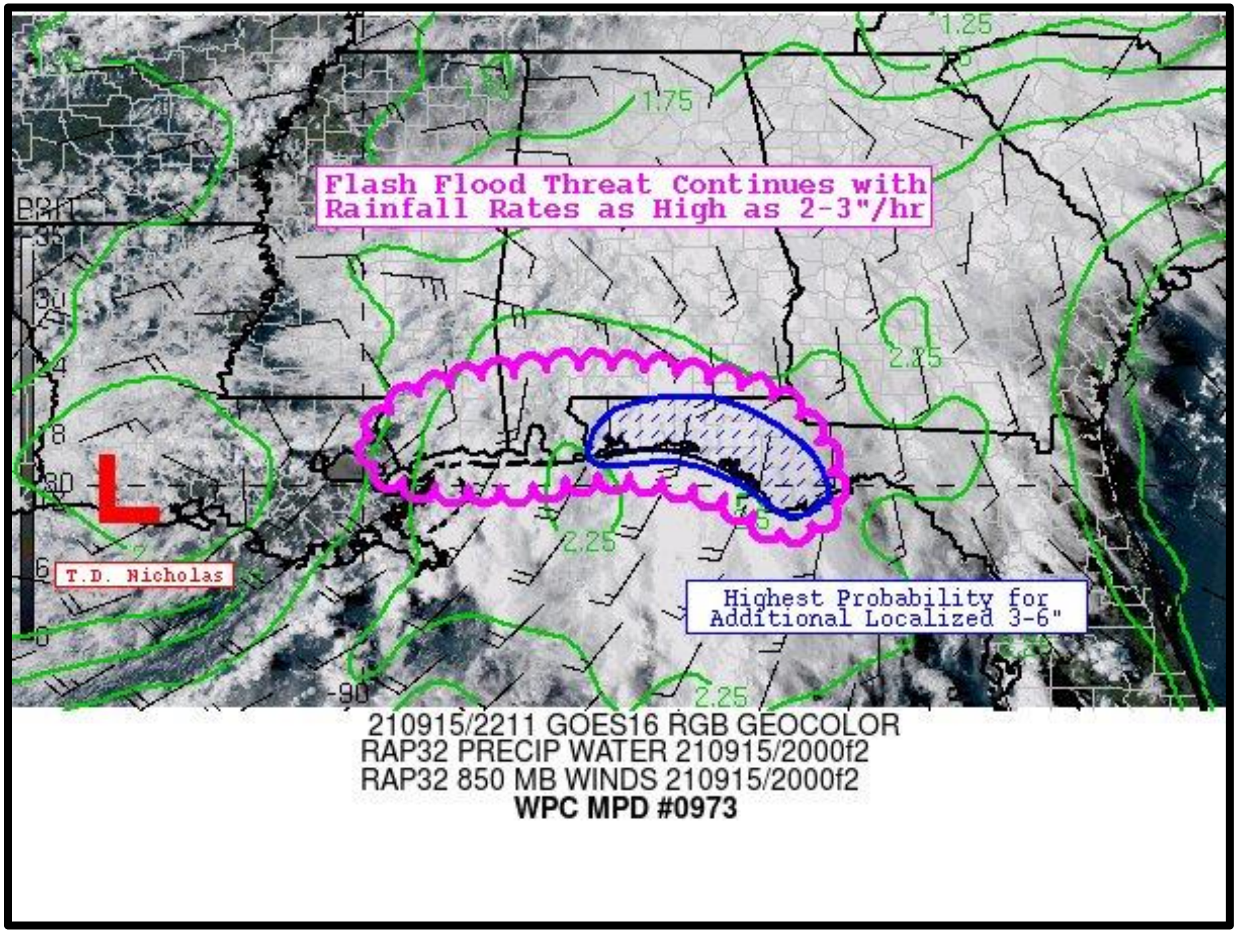

Figure 10. Mesoscale setup for the heavy rainfall event over southern Mississippi, Alabama, and the Florida Panhandle. Image courtesy of WPC.

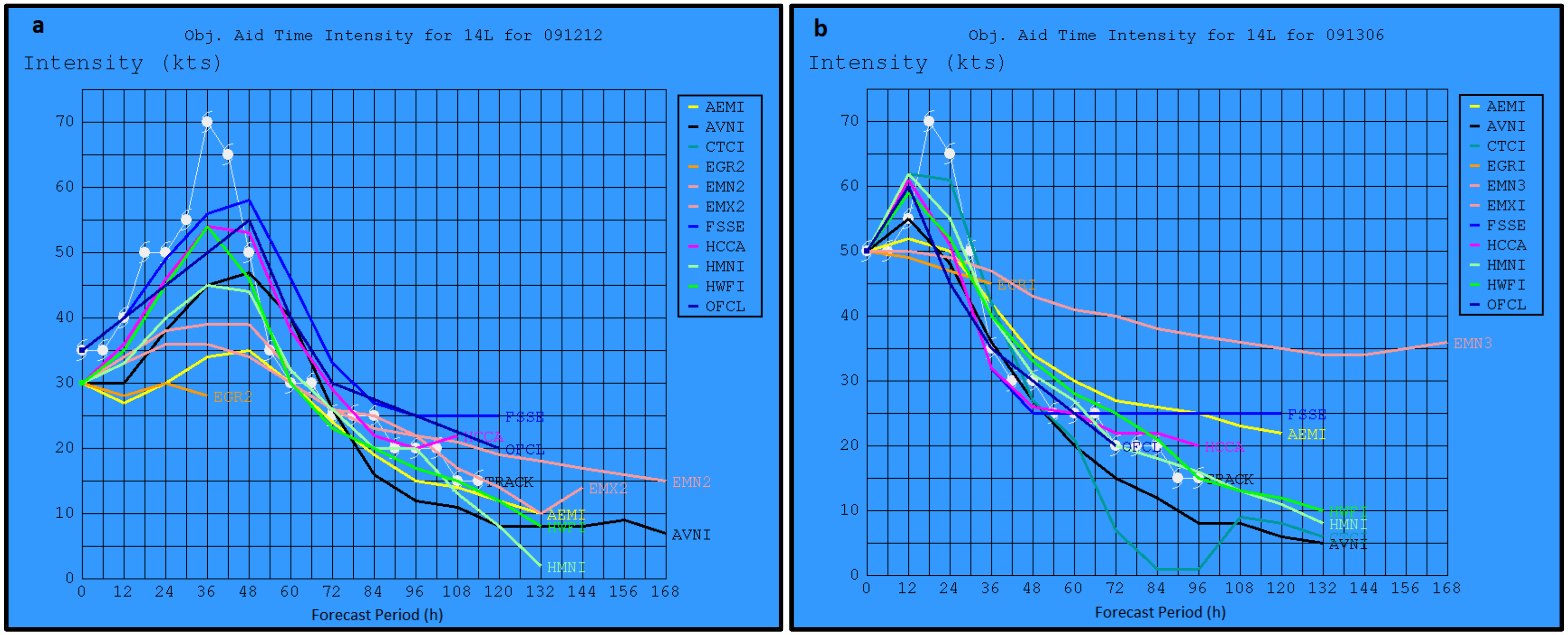

Figure 11. (a) NHC and model intensity forecasts for Nicholas valid for the 1200 UTC 12 September forecast cycle, the first official forecast for the cyclone. Nicholas's verifying intensity is indicated by the white line and symbols. (b) NHC and model intensity forecasts for Nicholas valid for the 0600 UTC 13 September forecast cycle.

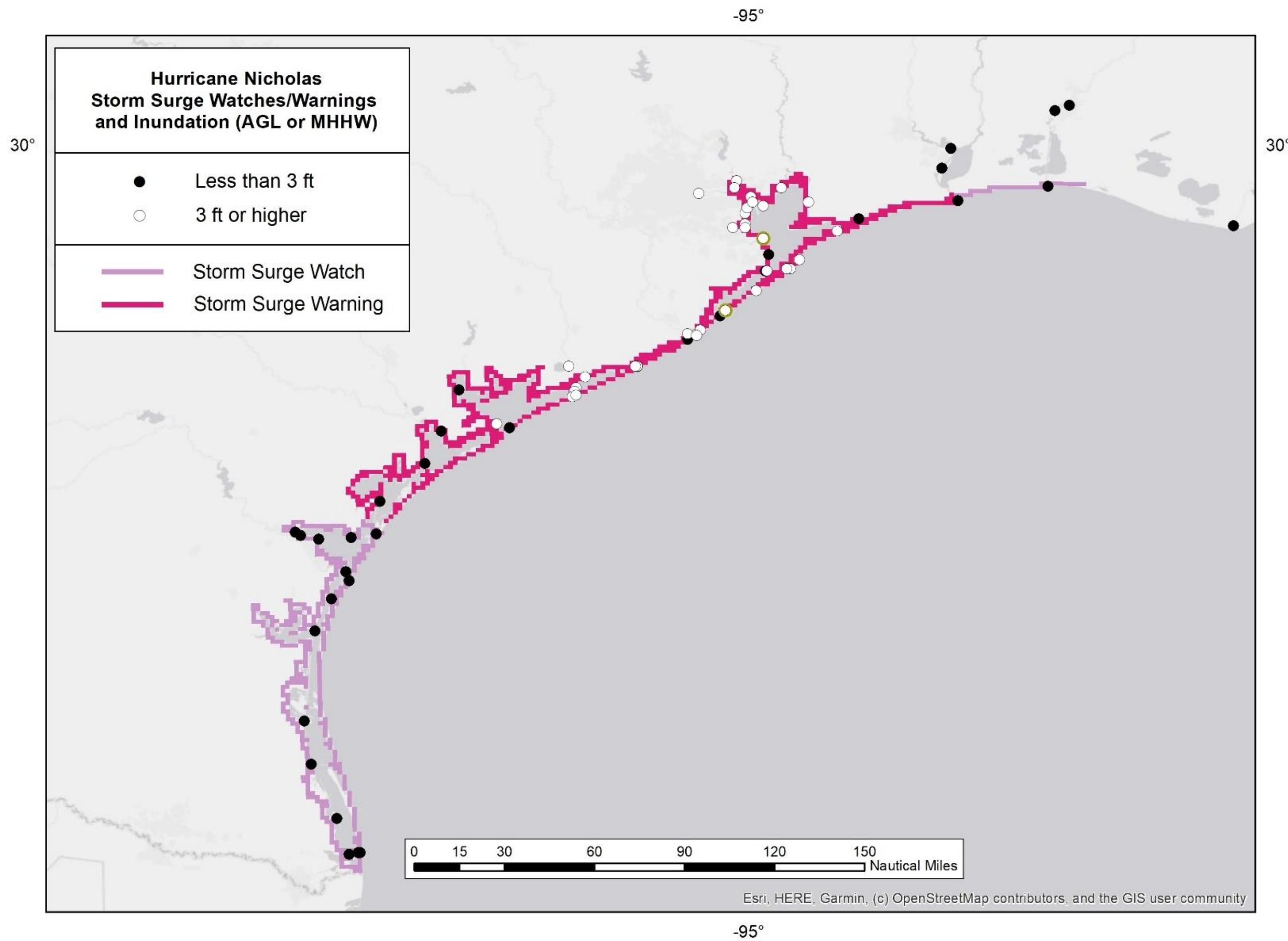

Figure 12. Maximum water levels measured during Hurricane Nicholas from tide and stream gauges and surveyed high water marks (circles), as well as areas covered by storm surge watches (lavender) and warnings (magenta). Water levels are referenced as feet above ground level (AGL) or Mean Higher High Water (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.