Tropical Cyclone Report
Hurricane Ike
(AL092008)
1 - 14 September 2008

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Ike was a long-lived Cape Verde hurricane that caused extensive damage and many deaths across portions of the Caribbean and along the coasts of Texas and Louisiana. It reached its peak intensity as a Category 4 hurricane (on the Saffir-Simpson Hurricane Scale) over the open waters of the central Atlantic, directly impacting the Turks and Caicos Islands and Great Inagua Island in the southeastern Bahamas before affecting much of the island of Cuba. Ike, with its associated storm surge, then caused extensive damage across parts of the northwestern Gulf Coast when it made landfall along the upper Texas coast at the upper end of Category 2 intensity.

a. Synoptic History

Ike originated from a well-defined tropical wave that moved off the west coast of Africa on 28 August. An area of low pressure developed along the wave axis early the next day and produced intermittent bursts of thunderstorm activity as it moved south of the Cape Verde Islands on 29 and 30 August. The low was unable to maintain organized deep convection for several days, but it is estimated that the system gained sufficient convective organization to be designated as a tropical depression by 0600 UTC 1 September, about 675 n mi west of the Cape Verde Islands and 1400 n mi east of the Leeward Islands. The "best track" chart of Ike's path is given in Figure 1, with the wind and pressure histories shown in Figures 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1]. The depression quickly strengthened to a tropical storm by 1200 UTC that day and then gradually intensified over the next two days as it moved west-northwestward over the tropical Atlantic, steered by a strong subtropical ridge to the north. During this period, Ike was surrounded by dry air and was unable to develop organized inner core convection, which possibly contributed to the slow rate of strengthening during the early part of the storm's existence.

Visible and microwave satellite imagery indicates that strong convective banding had begun to wrap around the center of Ike by 1200 UTC 3 September. An eye became apparent by 1800 UTC, and Ike became a hurricane at that time when it was centered about 600 n mi east-northeast of the northern Leeward Islands. Around this time, a deep-layer low pressure area over the northwestern Atlantic weakened the subtropical ridge and allowed Ike to move on a west-northwestward track. Northerly upper-level winds on the west side of the low were strong

[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.

enough to somewhat restrict the outflow on the north side of the hurricane although environmental conditions were otherwise favorable for intensification. Based on Dvorak satellite estimates, Ike is estimated to have strengthened from an intensity of 55 kt at 0600 UTC 3 September to its peak intensity of 125 kt (Category 4) at 0600 UTC 4 September—a 70-kt increase over a 24 h period. The 30-knot increase of winds between 1800 UTC 3 September and 0000 UTC 4 September ties Ike with four other Atlantic tropical cyclones for the fifth-fastest intensification rate over a 6-hour period. It should be stressed, however, that these wind estimates are based only on satellite observations since the hurricane was still out of range for sampling by aircraft reconnaissance.

After Ike reached its peak intensity, an upper-level high located northwest of the hurricane over the western Atlantic began to strengthen and contributed to 25-30 kt of northerly wind shear, causing the cloud pattern to become asymmetric. Weakening occurred over the next couple of days as the upper-level high continued to produce northeasterly shear over the storm, and Ike briefly fell below major hurricane status, with maximum sustained winds of 95 kt, at 1200 UTC 6 September. Microwave imagery at the time showed that much of the deep convection over the northern semicircle was severely eroded, including the northern eyewall, but a small eye remained present. Figure 4 shows a comparison of microwave images when Ike reached its peak intensity and after the shear had eroded the convection in the northern eyewall.

Building mid-level high pressure over the western Atlantic caused the hurricane to turn to the west late on 4 September. The high was strong enough to induce an unclimatological west-southwesterly motion by 0000 UTC 6 September. In fact, Ike is only the fifth tropical cyclone to reach a similar position in the Atlantic (near 24°N 60°W) and later move into the Gulf of Mexico, the last being Hurricane Andrew (1992). Ike went farther south and west than any of these storms, ultimately making landfall in Cuba and Texas.

Northeasterly shear relaxed over Ike early on 6 September while the hurricane was moving west-southwestward towards the Turks and Caicos Islands. The storm responded with deep convection redeveloping over the northern semicircle and quickly returned to Category 4 status by 1800 UTC 6 September. Although the center of Ike passed just south of the islands around 0600 UTC 7 September, the northern eyewall passed directly over Grand Turk, Salt Cay, South Caicos, and a few other smaller cays. Ike then weakened slightly to Category 3 status, with maximum sustained winds of 110 kt, before making landfall on Great Inagua Island in the southeastern Bahamas around 1300 UTC 7 September.

Ike weakened a little more after passing over Great Inagua, but this trend was short-lived. By the afternoon of 7 September, Ike once again re-strengthened to Category 4 status with winds of 115 kt by 0000 UTC 8 September. Ike made landfall at that intensity about two hours later near Cabo Lucrecia, Cuba, in the state of Holguín and near the city of Banes. The center of the hurricane traversed the states of Holguín, Las Tunas, and Camagüey during the early morning hours of 8 September, and Ike gradually lost strength, emerging over the waters of the northwestern Caribbean Sea around 1500 UTC with maximum sustained winds of 75 kt. Over the next day or so, Ike moved westward and maintained an intensity of 70 kt as its center hugged the southern coast of Cuba, at some points no more than 5-10 n mi offshore. Ike made a second landfall in Cuba around 1400 UTC 9 September near Punta La Capitana in the state of Pinar del

Rio, not far from the city of San Cristóbal, then emerged over the Gulf of Mexico around 2030 UTC.

Ike's interaction with Cuba caused much of the hurricane's inner core to become disrupted, and the wind field expanded as the hurricane moved into the Gulf of Mexico. The storm moved slowly northwestward on 10 September over the southeastern Gulf, and an eyewall replacement began with outer banding beginning to enclose the small eyewall that had survived the crossing of Cuba. This likely prevented rapid intensification, and Ike's winds only strengthened to 85 kt by 1800 UTC 10 September. In addition, the extent of tropical storm and hurricane force winds increased, reaching as far as 240 n mi and 100 n mi, respectively, from the center.

The subtropical ridge re-strengthened by late on 10 September and caused Ike to turn back to the west-northwest. The outer wind maximum started to contract and become the more dominant feature, and the inner wind maximum dissipated by 1800 UTC 11 September. Through the next day on 12 September, Ike continued to lack inner core convection and maintained its large wind field, making it difficult for the system to intensify quickly.

Ike reached the western periphery of the subtropical ridge and turned to the northwest towards the upper Texas coast late on 12 September. Microwave images and aircraft reconnaissance reports indicate that a 40 n mi diameter eye formed during the hours before landfall, and maximum winds increased to 95 kt. Ike turned to the north-northwest, and its center made landfall along the north end of Galveston Island, Texas, at 0700 UTC 13 September. The hurricane's center continued up through Galveston Bay, just east of Houston, then northward across eastern Texas. Ike weakened to a tropical storm by 1800 UTC 13 September just east of Palestine, Texas, and then became extratropical when it interacted with a front around 1200 UTC 14 September while moving northeastward through northern Arkansas and southern Missouri. The vigorous extratropical low moved quickly northeastward, producing hurricane-force wind gusts across the Ohio Valley on the afternoon of the 14 September. Thereafter, the low weakened and moved across southern Ontario and southern Québec and was absorbed by another area of low pressure near the St. Lawrence River by 1800 UTC 15 September.

b. Meteorological Statistics

Data sources for Ike (Figures 2 and 3) include satellites, aircraft, airborne and ground-based radars, conventional land-based surface and upper-air observing sites, Coastal Marine Automated Network (CMAN) stations, National Ocean Service (NOS) stations, ocean buoys, and ships. Ship reports of winds of tropical storm force or greater associated with Ike are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Observations include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB). Microwave data and imagery from National Oceanic and Atmospheric Administration (NOAA), Defense Meteorological Satellite Program (DMSP), and National Aeronautics and Space

Administration (NASA), including the Tropical Rainfall Measuring Mission (TRMM), QuikSCAT, Aqua, and the U. S. Navy's WindSat, were useful in tracking Ike.

Aircraft observations include flight-level, SFMR, and dropwindsonde observations, as well as 64 center fixes, from 16 operational missions into Ike by the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. One additional mission was flown in conjunction with the NOAA G-IV for synoptic surveillance east of Florida and another was flown to drop buoys over the central Gulf of Mexico ahead of Ike. In addition, the NOAA Aircraft Operations Center WP-3D aircraft flew 12 missions before, during, and after Ike. These were mainly for research purposes but still provided important data for operational use, including 15 additional center fixes. The NOAA G-IV jet flew eight synoptic surveillance missions around Ike.

NWS WSR-88D Doppler radars from Key West, Florida, New Orleans and Lake Charles, Louisiana, and Houston/Galveston, Texas, were used to make center fixes and obtain velocity data while Ike was near the coast. Several inland Doppler radars, including radars at Fort Polk and Shreveport, Louisiana, and Little Rock, Arkansas, were also used for center fixes and velocity data once Ike moved inland. Data from multiple radar sites in Cuba were extremely helpful in tracking Ike as it moved across the island.

Winds and Pressure

Ike is estimated to have reached its peak intensity before it was sampled by reconnaissance aircraft. The estimated maximum sustained winds of 125 kt and minimum central pressure of 935 mb at 0600 UTC September 4 are based on subjective Dvorak data T-number estimates and 3-hour averaged Advanced Dvorak Technique (ADT) estimates of 127 kt from the University of Wisconsin Cooperative Institute for Meteorological Satellite Studies. Dvorak final T-number estimates from TAFB and SAB were both 115 kt at the time, but Ike had just gone through a period of rapid intensification, strengthening faster than allowed by the Dvorak technique rules. Therefore, the raw data T-numbers and the shorter-term ADT averages likely provided a better intensity estimate.

A Hurricane Hunter mission on the afternoon of 6 September, just as Ike was approaching the Turks and Caicos Islands, measured a maximum flight-level wind of 129 kt and an SFMR estimate of 114 kt, supporting an increase in intensity to 115 kt. A reporting station on Grand Turk (78118) measured a sustained wind of 101 kt as the northern eyewall moved across the island. Maximum flight-level winds changed very little during the next flight early on 7 September, and Ike is estimated to have had an intensity of 110 kt when it hit Great Inagua. Before reaching Cuba, microwave imagery and Cuban radar suggested that Ike was completing an eyewall replacement. The estimated landfall intensity in Cuba of 115 kt is based on an SFMR wind of 119 kt and a reduced mean boundary layer wind of 105 kt reported by a dropwindsonde.

The highest sustained winds reported in Cuba were 76 kt with a gust to 107 kt at Palo Seco, 77 kt with a gust to 104 kt at Puerto Padre, and 70 kt with a gust to 100 kt at Velasco (Table 3).

Aircraft reconnaissance reports indicated that Ike steadily intensified for about 18 h after moving off the northwestern coast of Cuba. However, both the aircraft data and microwave imagery showed that the hurricane had a structure which likely prevented rapid intensification. By 1800 UTC 10 September, the aircraft data suggest that Ike had two well-defined wind maxima of nearly equal strength. The unusually broad distribution of strong winds were associated with surface central pressures that were much lower than would be expected for the winds that were measured. The minimum pressure over the Gulf of Mexico was 944 mb near 0000 UTC 11 September based on a dropwindsonde from one of the NOAA missions. A central pressure this low would generally be associated with a 115-kt hurricane.

The estimated Texas landfall intensity of 95 kt is based on flight-level winds of 105 kt, SFMR winds up to 90 kt, and Doppler radar velocities from the Houston radar, which showed 114 kt winds at 6500 feet. The highest reported 1-minute sustained wind was 71 kt from a Texas Tech University Hurricane Research Team (TTUHRT) anemometer near Winnie, Texas, between Houston and Beaumont. The highest 3-second gust was 95 kt from a separate TTUHRT sensor near Hankamer, Texas. The pressure of 950 mb at landfall is based on a minimum pressure of 950.7 mb reported by a TTUHRT sensor at Port Bolivar near the entrance to Galveston Bay and a pressure of 951.7 mb reported at the Galveston Pleasure Pier.

The post-tropical remnant low of Ike produced strong wind gusts as it moved across the Ohio Valley into southeastern Canada (Table 7). Wind gusts to hurricane force were reported at Louisville, Kentucky, and Cincinnati, Columbus, and Wilmington, Ohio.

Storm Surge

While storm surge associated with Ike affected the Turks and Caicos Islands, southern Bahamas, and Cuba, there are no available measurements of water level heights from these areas. Unofficial reports and state television from Cuba indicate that storm surge, and large waves as high as 50 ft, washed over and damaged coastal homes and other structures in the city of Baracoa near Ike's first landfall in Cuba.

Higher-than-normal water levels affected virtually the entire U.S. Gulf Coast. As the hurricane grew in size, the large wind field pushed water towards the coastline well before Ike's center made landfall near Galveston, Texas. Figure 5 shows maximum storm surge levels at various NOS tide stations, first occurring near the southwestern coast of Florida then migrating north and west along the Gulf Coast with time as Ike moved through the Gulf of Mexico.

NOS tide gauges (referenced to Mean Lower Low Water) indicate that storm surge along the west coast of Florida was generally 1 - 3 ft. Key West, Florida, measured a maximum storm surge of 1.66 ft at 1630 UTC 9 September. The highest water levels were subsequently recorded farther north along the west coast, and a maximum surge of 3.35 ft at Pensacola occurred around two days later at 2348 UTC 11 September.

Maximum storm surge along the coasts of Alabama, Mississippi, and southeastern Louisiana was generally in the 3 - 6 ft range. Dauphin Island, Alabama, recorded a storm surge of 3.27 ft, and Grand Isle, Louisiana, measured a surge of 3.84 ft. The concave orientation of the

coastline in this region caused the highest surge values to occur along the coast of Mississippi and Louisiana east of the Mississippi River, including the New Orleans and Lake Pontchartrain areas. The Bay Waveland Yacht Club, Mississippi, measured a maximum surge of 5.81 ft while New Canal Station near New Orleans recorded a surge of 5.24 ft. The surge of 7.51 ft at Shell Beach, Louisiana, was higher than that recorded within most of the neighboring region.

Storm surge heights increased dramatically west of Grand Isle, Louisiana, and were generally 5 - 10 ft along the coast of south-central Louisiana, increasing to 10 - 13 ft along the southwestern Louisiana and extreme upper Texas coast near Sabine Pass and Port Arthur. Several United States Geological Survey (USGS) sensors, referenced to the North American Vertical Datum of 1988 (NAVD88), indicate that isolated areas in Jefferson County, Texas, and Cameron Parish, Louisiana, had surge heights up to 17 ft. The highest storm surge measured by any NOS tide gauge was at Sabine Pass North, Texas, where 12.79 ft was recorded at 0748 UTC 13 September, just as Ike was making landfall at Galveston. Port Arthur, located several miles inland at the head of Sabine Lake, measured a maximum surge of 11.03 ft.

The highest storm surge occurred on the Bolivar Peninsula and in parts of Chambers County, Texas (including the east side of Galveston Bay), roughly between the Galveston Bay entrance and just northeast of High Island. Complete tide gauge records for this area are unavailable since many of the sensors failed from salt water intrusion and large wave action, although ground assessment teams determined that the surge was generally between 15 and 20 ft. The highest water mark, collected by FEMA (referenced to NAVD88), was 17.5 ft located about 10 n mi inland in Chambers County. Figures 6 and 7 show that water depths of at least 4 ft covered all of the Bolivar Peninsula, with most areas covered by at least 10 ft of water (not including wave action). Much of the southern part of Chambers County was also inundated by at least 10 ft of water.

Storm surge levels on Galveston Island and on the west side of Galveston Bay are estimated to be between 10 and 15 ft. Here, too, several NOS tide gauges failed, although the gauge at Eagle Point on the west side of Galveston Bay recorded a maximum surge of 11.48 ft. The highest inundation, of at least 10 ft, occurred on the bay side of Galveston Island, the coast of mainland Galveston County, as well as over Apffel Park at the northern tip of Galveston Island where Ike made landfall (Figure 6).

NOS tide gauges indicated that water levels along the Texas and southwest Louisiana coasts began to rise rapidly on 12 September, approximately 24 h before the time of landfall. Numerous media reports the day before landfall showed water had already flooded areas near the coast and cut off evacuation routes from areas such as the Bolivar Peninsula, well before strong winds had reached the coast. By the evening of 12 September, about 6 - 8 h before landfall, storm tides were already running near 8 ft in the vicinity of Galveston.

Farther south along the Texas coast, storm surge of 5 - 10 ft was recorded in Brazoria County, including near Freeport. The highest recorded stillwater mark in the area was 10.69 ft. The remainder of the Texas coast south of Brazoria County recorded surge heights of 2 - 5 ft.

Rainfall

Although rainfall observations were scarce from the Turks and Caicos Islands and the southern Bahamas, several reports from the Morton Salt Company indicated that 5 - 7 inches of rain fell on Great Inagua. Comprehensive rainfall amounts from Haiti are also not available, but heavy rains there caused more flooding and mud slides in areas that were still recovering from Tropical Storm Fay and Hurricanes Gustav and Hanna. Cuba reported heavy rainfall on some parts of the island. In Cuba, the highest reports were 13.77 inches from Júcaro in the province of Ciego de Ávila and 12.11 inches from Topes de Collantes in Sancti Spiritus. Table 3 lists rainfall amounts for selected reporting stations in the affected areas.

In the United States, Ike's outer rainbands produced some heavy rainfall over southern Florida. Highest reports were 6.33 inches near Ochopee and 5.98 inches near Chokoloskee. Figure 8 shows a map of accumulated rainfall from Ike over the United States. Ike produced a large area of rainfall 3 inches or greater over much of southeastern Texas and extreme southwestern Louisiana. The highest amount reported was 15.75 inches at White Oak Bayou in Houston. The remnants of Ike produced heavy rainfall and exacerbated flooding across portions of Missouri, Illinois, and Indiana initiated a day earlier by the remnant moisture from Pacific Tropical Storm Lowell and a frontal system.

Tornadoes

A total of 29 tornadoes were reported in association with Ike in the United States. Two tornadoes occurred in the Upper Florida Keys when the far outer spiral bands moved across the area. An EF0 tornado touched down in North Key Largo on 9 September, and an EF1 tornado touched down on Lower Matecumbe Key on 10 September, both producing minor damage. From 12 - 14 September, 17 tornadoes occurred in Louisiana, 1 in Texas, and 9 in Arkansas—none rated higher than an EF1. No deaths were reported from the tornadoes.

c. Casualty and Damage Statistics

Ike is directly responsible for 103 deaths across Hispaniola, Cuba, and parts of the United States Gulf Coast. Extensive damage from strong winds, storm surge, and rainfall occurred over Hispaniola, the Turks and Caicos Islands, the southern Bahamas, Cuba, and the U.S. Gulf Coast from Florida to Texas. Additional deaths and significant damage occurred across parts of the Ohio Valley and southeastern Canada after Ike lost tropical characteristics.

Hispaniola

Parts of Hispaniola, especially Haiti, were devastated by widespread flooding and mud slides from four consecutive impacts by Tropical Storm Fay and Hurricanes Gustav, Hanna, and Ike. Overall, 793 people died in Haiti from the four storms, with another 300 people reported missing. It is estimated that 74 deaths are directly attributable to the effects of Ike. Ike exacerbated the humanitarian disaster in Haiti, wiping out the food supply, shelter, and

transportation networks across the nation. Two deaths have been reported in the Dominican Republic.

Turks and Caicos Islands

The Caribbean Disaster Emergency Response Agency estimates that 95% of the houses on Grand Turk were damaged, 20% of which sustained significant damage. Ninety-five percent of the houses on South Caicos were damaged with over one-third significantly damaged or destroyed. Among the damaged buildings was Carnival Cruise Line's two-year old, $60 million cruise ship terminal on Grand Turk. In addition, the agricultural sector in North and Middle Caicos sustained damage and the fishing industry on South Caicos was significantly impacted. The airports in Providenciales, Grand Turk, and South Caicos were all flooded during the storm.

Bahamas

Approximately 70-80% of the houses on Great Inagua Island sustained roof damage, and 25% had major damage or were destroyed. The Morton Salt factory on the island was forced to halt operations as Ike damaged its offices and loading docks. A few West Indian flamingos were killed by Ike but most of the 50,000 flamingos in Inagua National Park—the world's largest breeding colony—survived by taking shelter within the park's mangroves or flying to other islands. Minor damage was reported to Mayaguana, Acklins, and Crooked Islands. Risk Management Solutions estimates that total damage costs are between $50 and $200 million (USD) for the Turks and Caicos and the Bahamas.

Cuba

Ike damaged 323,800 homes in Cuba, of which about 43,000 were a total loss, mainly in the provinces of Holguín, Las Tunas, Camagüey, Villa Clara, Santiago de Cuba, Guantanamo, Pinar del Rio, and the Isle of Youth. In advance of the hurricane, about 2.6 million people were evacuated, or about 23% of the entire Cuban population. Due to the massive evacuations and preparations, only seven direct deaths were reported due to falling structures and drowning.

Banana, coffee, yucca, and corn crops sustained serious damage across the country, and about 4,000 metric tons of foodstuffs were lost due to damage to storage facilities. Roadways sustained major damage across the island. In Ciego de Avila, the 24-km causeway linking mainland Cuba with the smaller islands of the Jardines del Rey archipelago, one of the major tourist destinations in the country, was damaged. The Granma Highway was severely damaged by storm surge, and the El Avispero bridge was washed away by a flooded river, stopping traffic along the coastal fringe of the Sierra Maestras. Several municipalities and communities were cut off from the rest of the country due to floodwaters. In Camagüey, the roofs and cupolas of several historic buildings were damaged, including the historic theater built in 1850. According to the United Nations, official sources in Cuba have estimated damages on the island to be between $3 and $4 billion (USD).

Florida

In the Florida Keys, almost 15,000 tourists evacuated as Ike approached. Tropical-storm-force winds caused some beach erosion on Key West's Smathers and Higgs Beaches and downed some tree limbs, but no major damage was reported. Commercial flights and cruise ship calls were temporarily halted until Ike passed.

Texas, Louisiana, and Arkansas

The latest official counts and media reports indicate that 20 people died in Texas, Louisiana, and Arkansas as a direct result of Ike. Twelve fatalities have been reported in Galveston and Chambers Counties, Texas, where the worst storm surge occurred, and several bodies were found within debris fields on the bay side of the Bolivar Peninsula, on Goat Island, and on the north side of Galveston Bay in Chambers County. Some of the debris fields have yet to be searched for remains due to lack of funds, and it is possible that the number of fatalities from storm surge could rise. Several of the deaths were Bolivar residents who did not leave after the first evacuation orders and were unable to leave once the rising waters cut off evacuation routes to the mainland. Three other drowning deaths were reported across Texas—one person drowned in the waters off Corpus Christi, one from storm surge in Orange County near Beaumont, and one after falling off a boat on Lake Livingston in Trinity County. In addition, one death in Montgomery County and one in Walker County resulted from trees falling onto the roofs of occupied houses. As many as 64 additional indirect deaths were reported in Texas due to factors such as electrocution, carbon monoxide poisoning, and pre-existing medical complications.

In Louisiana, a 16-year-old boy drowned in Bayou Dularge, and a man in Houma died after breaking his neck when a gust of wind blew him over.

One death occurred in Fisher, Arkansas, after a tree fell on a mobile home.

Reports from the Laura Recovery Center (http://www.lrcf.net/Ike/display.names.cgi) indicate that 38 people remain missing as of 23 January 2009, of which 21 are from Galveston, 5 from Port Bolivar, 2 from Crystal Beach, and 1 from Gilchrist.

The Property Claim Services of the Insurance Services Office estimates that the insured damage (not including inland flooding or storm surge) from Ike in Texas, Louisiana, and Arkansas is $8.45 billion dollars. The National Flood Insurance Program estimates that insured losses from inland flooding and storm surge is $489.5 million in the same three states. Because there is a $250,000 cap on each claim for inland flooding and storm surge, it is unlikely that this number is close to actual damage costs, considering the total devastation that occurred on some parts of the coast. Using these preliminary figures, total damage is estimated at about $18 billion dollars, based on a doubling of the total insured damage. These estimates suggest that Ike is the fourth costliest hurricane to affect the United States, after Hurricanes Katrina (2005), Andrew (1992), and Wilma (2005).

Significant storm surge and wave damage occurred along an extensive section of the upper Texas and southwestern Louisiana coast, with the worst devastation on the Bolivar Peninsula and parts of Galveston Island. Almost every structure on parts of the Bolivar Peninsula, including the communities of Crystal Beach, Gilchrist, and High Island, were completely razed from their foundations due to the surge and accompanying waves. Protected by a seawall, much of the city of Galveston was spared direct impact by storm surge and wave action from the Gulf of Mexico; however the city was still inundated by surge when water rose on the north side of the island from Galveston Bay (Figures 6 and 10). Ike downed numerous trees and powerlines across the Houston area, and many streets were blocked due to floodwaters. The U.S. Department of Energy estimated that 2.6 million customers lost power in Texas and Louisiana. Downtown Houston was spared significant wind damage, but streets were still littered with traffic signals and glass; one side of the 75-story JP Morgan Chase skyscraper, the city's tallest, was missing many of its windows. Large chunks of the retractable roof of Reliant Stadium, home of the National Football League's Houston Texans, were torn off during the storm, forcing the team to postpone a home game. In southwestern Louisiana, storm surge waters pushed up to 30 miles inland, including near Lake Charles, and inundated homes in parts of Cameron, lower Vermilion, St. Mary, and Terrebonne Parishes.

Ports from Corpus Christi to Lake Charles were closed in advance of Ike. Damage to the Ports of Galveston and Houston, as well as debris in Galveston Bay and the Houston Ship Channel, kept those ports closed after the storm for several days, leaving almost 150 tankers, cargo vessels, and container ships waiting offshore (Figure 7f). The U.S. Department of Energy said that 14 oil refineries were closed by the storm, as well as two Texas strategic petroleum reserve sites, causing rising gas prices and gas shortages across parts of the United States. In addition, the storm destroyed at least 10 offshore oil rigs and damaged several large pipelines. Before Ike reached the coast, a Cypriot freighter carrying petroleum coke, the 580-foot *Antalina*, lost propulsion about 90 miles southeast of Galveston with its 22-man crew. The U.S. Coast Guard could not rescue the crew during the storm due to the hazardous weather conditions, but the ship rode out the storm without casualties.

Ohio Valley

Although Ike became extratropical while moving northward over Arkansas, its remnants caused several deaths and produced significant wind damage across the Ohio Valley. At least 28 direct and indirect deaths were reported in Tennessee, Ohio, Indiana, Illinois, Missouri, Kentucky, Michigan, and Pennsylvania. In Ohio, almost 2.6 million people lost power with the most extensive damage reported in the areas near Cincinnati, Columbus, and Dayton. The Property Claim Services of the Insurance Services Office estimates that the post-tropical remnants of Ike produced $2.205 billion in non-flooding related insured losses—which equates to approximately $4.41 billion in damages. Insured losses in Ohio are estimated at $1.1 billion, rivaling the 1974 Xenia tornado as the costliest natural disaster in the state's history.

Canada

High winds and record rainfall were reported across portions of southern Ontario and Québec from the remnants of Ike. Downed power lines and tree branches in these areas left at

least 50,000 customers without power. Heavy rainfall caused some flooding and washed out several roads. High humidity associated with the system caused an electrical malfunction on one of the lines of the Montréal subway system, stranding commuters.

d. Forecast and Warning Critique

Genesis

The genesis of Ike was well anticipated, even before the antecedent tropical wave moved off the coast of Africa. The Atlantic Tropical Weather Outlook (TWO) first mentioned the wave at 1200 UTC 28 August just as it was about to move off the coast, stating that gradual development was possible over the next couple of days. At this point, the system was given a "medium" chance to develop into a tropical cyclone within the following 48 h. By 1200 UTC 29 August, 66 h prior to genesis, the TWO explicitly mentioned that a tropical depression could form over the next couple of days. The genesis probability was elevated to "high" at 0600 UTC 30 August, exactly 48 h prior to the formation of a tropical depression.

Track

A verification of official and guidance model track forecasts is given in Table 4. Average official track errors for Ike (with number of cases in parentheses) were 17 (50), 32 (48), 46 (46), 59 (44), 91 (40), 121 (36), and 166 (32) n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. These errors are significantly lower than the average official track errors (Table 4), ranging from a 50% improvement for the 12 h forecast to a 39% improvement for the 120 h forecast. The official track forecasts were better than most of the available guidance, with a few exceptions. Impressively, the official track forecasts were better than the GUNA consensus at all forecast times and were only bested by the TVCN consensus at the 72 and 120 h period. The only single model that consistently outperformed the official forecast was the European Center for Medium-Range Weather Forecasts global model (EMXI). EMXI showed particular skill at the 36-120 h forecast times, where it performed 20-26% better than the official track forecast.

There were three periods during the life of Ike during which most of the track model guidance showed a consistent bias. The first was around the time Ike reached its peak intensity north of the Leeward Islands just before it was driven west-southwestward by the subtropical high. The track model guidance during this period had a considerable northward bias, with many of the models showing a less pronounced west-southwestward motion and a subsequent turn to the northwest across the Bahamas towards South Florida. Only the GFDI and EMXI performed well during this period by anticipating the west-southwestward motion towards eastern Cuba (Figure 9).

After the west-southwestward dive towards Cuba, model guidance indicated that Ike would reach the western periphery of the ridge and turn to the northwest. A few of the models, such as the GFDI, HWFI, and NGPI, were too quick with this scenario and brought Ike over the southeastern Gulf of Mexico closer to the west coast of Florida. The GFSI and EMXI performed

much better during this period and were much closer to the actual track of Ike, whereas the EGRI actually showed a slight left-of-track bias closer to the Yucatan Peninsula.

Ike's Texas landfall also highlighted certain model biases as the storm was moving into the Gulf of Mexico. The 2100 UTC 8 September forecast issued by National Hurricane Center (NHC), when Ike was still located near the southern coast of Cuba, indicated a U.S. landfall somewhere just south of Galveston Bay by 1800 UTC 13 September. However, in the following days many of the models were indicating a strong high developing over the southern U.S. and responded by showing a landfall farther south between Corpus Christi and Brownsville (the 0900 UTC 9 September forecast was the farthest south). After that point, the models began a slow shift back to the north as it became more apparent that the high would not be strong enough to induce the westward motion. Again, only the EMXI showed more consistent and skillful forecasts, never deviating from a landfall somewhere between High Island and far eastern Matagorda Bay. Most of the other major dynamical models showed a persistent westward bias over the western Gulf of Mexico several days before the landfall (Figure 9). While the NHC cone graphic highlighted the area at risk through this period, more quantitatively useful information was provided by the wind speed and experimental storm surge probability products.

Intensity

A verification of official and guidance model intensity forecasts is given in Table 5. Average official intensity errors for Ike (with number of cases in parentheses) were 8 (50), 11 (48), 13 (46), 14 (44), 18 (40), 18 (36), and 24 (32) knots for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. These are close to the average 5-year official intensity errors for the Atlantic (7, 10, 12, 14, 18, 20, and 22 kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively). Several challenges in forecasting the intensity of Ike include its rapid intensification over the western Atlantic, the long periods of interaction with land (especially Cuba), and the anomalous structure the hurricane exhibited while over the Gulf of Mexico.

The NHC official forecasts did outperform many of the individual intensity models. Only the GHMI (at the 96 and 120 h periods) and the FSSE (at the 72-120 h periods) had smaller errors than the official intensity forecasts. However, the intensity model consensus (ICON) bested the official forecasts at all times except the 36 h period.

Watches and Warnings

Watches and warnings associated with Ike are given in Table 6. The government of the Bahamas first issued a hurricane watch for the Turks and Caicos Islands and the southeastern Bahamas approximately 24 h before tropical storm force winds began to spread across the easternmost Turks and Caicos but almost 33 h before these winds reached Great Inagua Island in the southeastern Bahamas. The watch was also issued 33 and 39 h before hurricane force winds reached the Turks and Caicos Islands and Great Inagua Island, respectively.

The government of Cuba issued a hurricane watch for the easternmost Cuban provinces from Guantanamo to Camagüey approximately 21 h before tropical storm force winds began spreading across the eastern end of Cuba and about 33 h before hurricane force winds reached

the area around Cabo Lucrecia. Subsequent hurricane watches and warnings were issued for the entire length of Cuba.

A hurricane watch was issued for the Florida Keys from Ocean Reef to the Dry Tortugas when Ike was located over Great Inagua Island, with the anticipation that the hurricane would move close to the island chain. Although hurricane force winds remained well south of the keys, a tropical storm warning was required for the same area, including Florida Bay, and was issued approximately 24 h before tropical storm force winds began to spread across portions of the Middle and Lower Keys. Much of the Upper Keys remained outside the area of tropical storm force winds.

After Ike moved into the Gulf of Mexico, a hurricane watch was issued on the afternoon of 10 September from Cameron, Louisiana, to Port Mansfield, Texas, while a tropical storm warning was issued from the mouth of the Mississippi River to Cameron. The issuance of the tropical storm warning for parts of the Louisiana coast, without the previous issuance of a tropical storm watch, was required due to the unforeseen rapid expansion of Ike's wind field once the storm moved across Cuba. However, the warning was still issued with appropriate lead time as tropical storm force winds began to affect the Mississippi Delta region about 24 h later. A hurricane watch was issued from Cameron, Louisiana, to Port Mansfield, Texas, earlier than the usual 36-hr threshold since significant storm surge was expected to impact the area well before tropical-storm-force winds reached the coast. A hurricane warning was issued from Morgan City, Louisiana, to Baffin Bay, Texas about 24 h before storm surge began to affect the region.

Acknowledgments

Weather Service Forecast Offices (WFOs) in Miami, Key West, Tampa, Mobile, New Orleans, Lake Charles, Houston/Galveston, Shreveport, Corpus Christi, Brownsville, Ft. Worth, and the National Data Buoy Center provided extensive post-storm reports and provided the many observations included in Table 3. WFOs in Little Rock, Paducah, Louisville, Indianapolis, Wilmington (OH), and Cleveland provided additional storm reports for Ike's post-tropical remnants. The Instituto de Meteorología de la República de Cuba also provided a post-storm summary and observations. The National Ocean Service and the Harris County Flood Control District provided storm surge charts and graphics. David Roth at the Hydrometeorological Prediction Center provided the rainfall graphic. The Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy provided information on Ike's effects on the electrical grid and oil refineries. The Hurricane Specialists Unit and the Storm Surge Unit at the National Hurricane Center provided extensive insight and guidance in the writing of this report. Damage pictures in Figure 10 are from the *Houston Chronicle*, WFO Houston/Galveston, the Galveston County Office of Emergency Management, and the USGS. The NOAA Hurricane Research Division, NOAA Aircraft Operations Center Hurricane Hunters, and the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command spent countless hours gathering crucial data for Ike.

Table 1. Best track for Hurricane Ike, 1 – 14 September 2008.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
01 / 0600	17.2	37.0	1006	30	tropical depression
01 / 1200	17.3	38.4	1005	35	tropical storm
01 / 1800	17.5	39.9	1003	45	"
02 / 0000	17.8	41.3	1002	45	"
02 / 0600	18.2	42.8	1000	45	"
02 / 1200	18.7	44.3	999	50	"
02 / 1800	19.3	45.8	996	55	"
03 / 0000	19.8	47.3	994	55	"
03 / 0600	20.2	48.8	992	55	"
03 / 1200	20.6	50.3	989	60	"
03 / 1800	21.1	51.9	979	75	hurricane
04 / 0000	21.8	53.5	956	105	"
04 / 0600	22.4	55.0	935	125	"
04 / 1200	23.0	56.4	937	120	"
04 / 1800	23.4	57.7	940	115	"
05 / 0000	23.6	59.0	944	115	"
05 / 0600	23.6	60.4	949	115	"
05 / 1200	23.5	61.9	954	105	"
05 / 1800	23.2	63.4	959	100	"
06 / 0000	22.8	64.9	962	100	"
06 / 0600	22.4	66.3	964	100	"
06 / 1200	21.9	67.7	965	95	"
06 / 1800	21.5	69.0	950	115	"
07 / 0000	21.2	70.3	947	115	"
07 / 0600	21.1	71.6	947	115	"
07 / 1200	21.0	72.8	947	110	"
07 / 1800	21.0	74.0	946	105	"
08 / 0000	21.1	75.2	945	115	"
08 / 0600	21.1	76.5	950	100	"
08 / 1200	21.1	77.8	960	85	"
08 / 1800	21.2	79.1	964	75	"
09 / 0000	21.5	80.3	965	70	"
09 / 0600	22.0	81.4	965	70	"

09 / 1200	22.4	82.4	965	70	"
09 / 1800	22.8	83.3	966	65	"
10 / 0000	23.1	84.0	968	65	"
10 / 0600	23.4	84.6	964	70	"
10 / 1200	23.8	85.2	959	80	"
10 / 1800	24.2	85.8	958	85	"
11 / 0000	24.7	86.4	944	85	"
11 / 0600	25.1	87.1	945	85	"
11 / 1200	25.5	88.0	946	85	"
11 / 1800	25.8	88.9	952	85	"
12 / 0000	26.1	90.0	954	85	"
12 / 0600	26.4	91.1	954	90	"
12 / 1200	26.9	92.2	954	90	"
12 / 1800	27.5	93.2	954	90	"
13 / 0000	28.3	94.0	952	95	"
13 / 0600	29.1	94.6	951	95	"
13 / 1200	30.3	95.2	959	85	"
13 / 1800	31.7	95.3	974	50	tropical storm
14 / 0000	33.5	94.9	980	35	"
14 / 0600	35.5	93.7	985	35	"
14 / 1200	37.6	91.0	987	40	extratropical
14 / 1800	40.3	87.2	988	50	"
15 / 0000	43.3	81.5	988	50	"
15 / 0600	45.8	75.3	986	40	"
15 / 1200	47.2	71.1	986	35	"
15 / 1800					absorbed by another low
04 / 0600	22.4	55.0	935	125	maximum wind and minimum pressure
07 / 1300	21.0	73.2	947	110	landfall on Great Inagua Island, Bahamas
08 / 0215	21.1	75.7	945	115	landfall near Cabo Lucrecia, Cuba
09 / 1400	22.6	82.9	965	70	landfall near Punta La Capitana, Cuba
13 / 0700	29.3	94.7	950	95	landfall at north end of Galveston Island, Texas

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Ike, 1 – 14 September 2008.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
09 / 1200	C6FZ7	19.6	81.0	200 / 43	1008.2
09 / 1700	C6FZ7	19.5	79.2	170 / 43	1015.0
10 / 0900	WPKD	24.2	82.9	130 / 44	1000.0
10 / 1200	WPKD	24.6	83.7	130 / 55	995.5
10 / 1500	WPKD	25.3	83.9	110 / 59	1011.5
10 / 1800	WPKD	26.2	84.1	120 / 52	1002.5
10 / 2200	V7HC9	28.0	86.5	090 / 50	1009.3
11 / 0000	WPKD	27.3	84.3	110 / 44	1004.2
11 / 0000	V7HC9	28.1	86.4	050 / 52	1009.2
11 / 0200	V7HC9	28.1	86.3	100 / 45	1009.9
11 / 0600	C6FM5	21.8	86.8	220 / 45	1014.0
11 / 0600	V7HD3	28.7	87.0	090 / 50	1014.0
11 / 0900	WPKD	27.4	84.4	110 / 41	1007.0
11 / 0900	C6CL6	28.1	88.6	070 / 45	1008.0
11 / 1000	WDD382	27.8	88.9	070 / 44	1002.1
11 / 1000	V7HD3	28.7	87.0	110 / 60	1013.5
11 / 1100	WDD382	27.9	88.8	070 / 47	1002.5
11 / 1100	V7HC9	28.1	86.3	100 / 62	1008.5
11 / 1200	WDD382	27.9	88.6	090 / 47	1002.2
11 / 1200	C6CL6	28.1	88.4	090 / 46	1002.8
11 / 1200	3FMH7	28.6	88.8	190 / 48	1007.4
11 / 1200	V7HD3	28.7	87.0	090 / 44	1014.0
11 / 1300	WDD382	27.9	88.6	090 / 44	1002.0
11 / 1400	WDD382	27.9	88.4	090 / 52	1002.0
11 / 1500	WDD382	27.9	88.3	100 / 52	1001.5
11 / 1500	C6CL6	28.1	88.4	090 / 55	1003.0
11 / 1600	WDD382	27.9	88.2	100 / 52	1001.5
11 / 1700	WDD382	27.9	88.2	100 / 44	1002.0
11 / 1800	WDD382	27.9	88.0	120 / 49	1002.0
11 / 1800	V7HC8	28.1	89.0	080 / 42	1007.0
11 / 1800	C6CL6	28.2	88.3	090 / 55	1003.0
11 / 1800	3FMH7	28.7	88.3	080 / 54	1007.4

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
11 / 1900	WDD382	27.9	87.9	120 / 52	1012.5
11 / 2000	WDD382	27.9	87.8	120 / 44	1001.0
11 / 2000	V7HC8	28.1	88.9	110 / 45	1003.0
11 / 2000	V7HC9	28.1	86.3	180 / 50	1010.8
11 / 2100	WDD382	27.9	87.7	120 / 42	1001.5
11 / 2100	V7HC9	28.1	86.3	110 / 50	1010.2
11 / 2100	C6CL6	28.2	88.3	090 / 55	1003.0
11 / 2100	WPKD	28.3	85.8	120 / 41	1008.0
11 / 2200	WDD382	27.9	87.6	110 / 44	1001.5
11 / 2200	V7HC9	28.1	86.3	180 / 45	1010.2
11 / 2300	WDD382	27.8	87.4	100 / 44	1002.2
11 / 2300	V7HC8	28.2	88.9	100 / 45	1008.0
12 / 0000	KRGC	23.0	89.5	210 / 46	1002.0
12 / 0000	WDD382	27.8	87.3	110 / 44	1002.5
12 / 0000	C6CL6	28.2	88.2	100 / 48	1002.0
12 / 0000	3FMH7	28.7	88.0	120 / 43	1005.7
12 / 0100	WDD382	27.7	87.2	110 / 44	1003.5
12 / 0200	WDD382	27.6	87.0	130 / 41	1006.5
12 / 0200	V7HC9	28.1	86.3	110 / 47	1012.6
12 / 0300	C6CL6	28.2	88.0	110 / 55	1005.0
12 / 0600	C6CL6	28.1	87.9	140 / 58	1005.0
12 / 0600	3FMH7	28.5	87.7	120 / 46	1007.9
12 / 0600	WPKD	28.8	86.6	120 / 43	1009.8
12 / 0900	WGZK	23.6	92.1	220 / 41	1000.0
12 / 0900	C6CL6	28.0	87.8	140 / 55	1006.0
12 / 1200	WGZK	23.9	91.7	210 / 45	1000.7
12 / 1200	C6CL6	27.8	87.7	120 / 51	1007.8
12 / 1500	WGZK	24.3	91.2	210 / 44	1005.5
12 / 1500	C6CL6	27.6	87.6	130 / 48	1009.0
12 / 1800	C6CL6	27.3	87.5	170 / 50	1010.0
12 / 2100	C6CL6	27.0	87.5	160 / 45	1010.0
13 / 0000	C6CL6	26.7	87.5	160 / 42	1010.0

Table 3. Selected surface observations for Hurricane Ike, 1 – 14 September 2008.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Haiti								
Camp Perrin								2.23
Dominican Republic								
Santo Domingo								9.40
Barahona								8.86
Aerop. Joaquin Balaguer								8.75
Polo								8.15
San Cristobal								7.63
Yamasa								7.33
Rancho Arriba								6.74
Neyba								4.49
Monte Plata								4.19
Juma Bonao								4.11
Aeropuerto Catey								4.09
Bonao								4.01
Punta Cana								2.17
Santiago								1.80
Turks and Caicos Islands								
Grand Turk (78118)	07/0300	975.3	07/0300	101				
Pine Cay (DW0758)	07/0312	991.8	07/0358	57	62			
Pine Cay (MD0758)	07/0333	992.4	07/0412	57				
Bahamas								
Great Inagua								
#4 Pump								6.48
P. Point								6.90
Y-2								5.48
Y. House								6.90

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Cuba								
Holguín								
La Jíquima	08/0600	956.0	08/0635	59	84			6.51
Guaro	08/0220	980.0	08/0220	60	86			5.00
Holguín	08/0400	972.5	08/0412	68	97			5.73
Velasco	08/0420	949.0	08/0440	70	100			4.84
Las Tunas								
Las Tunas	08/0700	952.5	08/0625	65	93			4.10
Puerto Padre	08/0650	950.5	08/0525	77	104			6.84
Camagüey								
Florida	08/1300	984.6	08/0830	49	69			11.88
Santa Cruz del Sur	08/1150	992.9	08/1035	48	65			5.83
Esmeralda	08/1200	997.0						3.94
Nuevitas	08/0830	987.8	08/0804	71	96			5.05
Palo Seco	08/0830	945.5	08/0759	76	107			5.98
Camagüey			08/0935	53	76			8.39
Santiago de Cuba								
Contramaestre	08/0700	995.2	08/1655	23	38			2.65
Santiago de Cuba	08/0600	1001.2	08/1200	29	49			5.06
La Gran Piedra			08/1100		71			
Granma								
Cabo Cruz			08/1620	49	65			1.30
Manzanillo			08/0841	35	49			2.96
Jucarito			08/0754	48	68			3.11
Veguitas			08/0850	32	46			3.05
Guantánamo								
Guantánamo			07/1650	25	37			3.93
Punta de Maisí	07/1500	990.8	07/2315	61	83			5.89
Jamal, Baracoa	07/1600	992.9	07/1740		76			6.95
Palenque de Yateras	07/2300	987.7	07/2030		65			10.63
Valle de Caujerí			08/0000	31	51			6.72

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Ciego de Ávila								
Falla	08/1810	995.0	08/1700	49	70			6.32
Ciego de Ávila	08/1700	994.9	08/1800	48	68			9.28
Júcaro	08/1700	991.2	08/1800	55	75			13.77
Cayo Coco	08/1140	1003.3	08/1908	51	69			1.66
Sancti Spíritus								
Sancti Spíritus	08/2230	990.2	08/2100	37	62			9.76
Topes de Collantes			08/2238		78			12.11
Trinidad	08/2300	976.1	08/2259	43	71			4.41
El Jíbaro	08/2050	986.5	08/1802	47	67			8.18
Villa Clara								
Sagua la Grande	08/2100	1000.0	08/1940	50	67			3.73
Santa Clara	08/2200	983.0	08/1928	43	62			3.46
Caibarién	08/2300	998.0	08/2145	49	65			2.91
Santo Domingo	08/1900	992.5	08/2020	42	59			4.16
Cienfuegos								
Aguada de Pasajeros	09/0300	994.3	09/0030	43	62			7.72
Cienfuegos	09/0000	989.0	08/1830	45	64			3.08
Matanzas								
Playa Girón	09/0400	986.5	09/1300	48	65			3.72
Varadero			09/0445	48	64			2.54
Unión de Reyes	09/0900	993.7	09/0150	42	59			10.24
Colón	09/0720	996.6	09/0050	42	59			8.28
Jovellanos	09/0700	996.4	09/0300	42	59			5.59
Indio Hatuey	09/0600	997.9						6.72
Jagüey Grande								9.11
La Habana								
Güines	09/1200	992.4	09/1114	54	77			4.42
Bainoa		982.7	09/0420	36	59			5.76
Bauta		984.6	09/1605	46	66			8.46
Melena del Sur	09/1200	988.6	09/1202	41	58			6.80

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Güira de Melena	09/1300	987.5	09/0710	37	52			6.13
Batabanó	09/1200	986.6	09/0605	42	59			4.67
Ciudad de La Habana								
Casa Blanca	09/1220	989.7	10/0045	49	70			3.35
Santiago de las Vegas		982.7	09/1148	39	56			7.70
Isla de la Juventud								
La Fe	09/1200	991.4	09/1600	36	51			1.37
Pinar del Río								
Cabo de San Antonio	10/0600	996.2	10/1335	49	66			2.30
Santa Lucía	09/2200	984.0	10/1425	39	56			3.14
Isabel Rubio	09/2000	984.2	09/2305	34	47			9.01
San Juan y Martínez	09/2225	989.2	10/1209	41	58			7.86
Pinar del Río	10/1500	980.6	10/1150	41	59			8.95
La Palma	09/1900	965.9	09/1845	48	68			11.09
Paso Real de San Diego	09/1640	960.8	09/1658	72	103			11.91
Bahía Honda	09/1800	986.2	09/1445	43	58			4.64
Florida								
International Civil Aviation Organization (ICAO) Sites								
Boca Chica NAS (KNQX)			09/1736	39	52			
Fort Myers (KFMY)								5.01
Hollywood (KHWO)	09/0853	1010.5	09/1833	27	36			
Homestead (KHST)	09/1917	1009.5	09/1141	24	37			
Key West (KEYW)	09/2051	1004.4	09/1747	45	52			2.31
Marathon (KMTH)	09/0836	1005.4	09/0906	30	43			2.47
Opa Locka (KOPF)	09/0853	1009.8	10/0040	34	40			
St. Petersburg (KSPG)	09/1953	1010.0	10/1153	20	40			
West Kendall (KTMB)	09/0853	1008.8	09/1657	28	36			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
RAWS[f]								
Big Pine Key – Key Deer NWR (TS607)			09/0338	21	38			
Big Pine Key			09/1350	27	36			
Ochopee 2 NE (OCOF1)								6.33
CWOP[g]								
Cudjoe Key (CW0925)	09/0931	1004.4	09/0311	30	42			
Long Key (CW0922)	09/0830	1005.4	09/1040	44	55			2.37
Ramrod Key (CW0924)	09/0830	1004.3	09/0311	32	43			
SFWMD[h]								
Belle Glade (BELLW)			09/1800	20[e]	35			
Chokoloskee (BCA19)								5.98
Far NW Miami-Dade County (G3ASWX)			09/1515	25[e]	37			
Far Western Broward County (S140W)			09/1845	20[e]	35			
Loxahatchee Wildlife Refuge (LXWS)			09/1700	20[e]	34			
Redland (S331W)			09/1515	25[e]	36			
Other								
South Key Largo (Weatherflow)			09/1905	27	39			
Upper Matecumbe Key (Weatherflow)			09/1255	37	53			
USCGG Key West (Weatherflow)			09/1310	33	50			
Medley (XURB)			09/1455	25[e]	38			
NWS Key West (KKEY)			09/1820		57			
Sunshine Skyway Bridge			09/2036		52			
Marine								
Belle Meade (XCAP)			09/1600	20[e]	34			
Big Carlos Pass COMPS	10/1800	1010.0	10/1100	25	35			
Cedar Key						2.00	5.80	
Clearwater Beach						1.90	4.80	
COMPS Buoy (C10)	10/2120	1009.0	09/2140	31	34			
Deering Bay (XCUT)			09/1545	25[e]	37			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Destin (EPSF1)						2.45	3.95	
Everglades City (KEGC)			10/1045	27	43			
Flamingo (KFLM)			09/1246	45	55			
Fowey Rocks (FWYF1)			09/1210	35	44			
Key West Harbor						1.20	2.20	
Long Key Light (LONF1)	09/0900	1006.7	09/0500	34	50			
Marco Island (Mesonet)			09/1600		34			
Molasses Reef Light (MLRF1)	09/0900	1007.0	09/0700	40	49			
Naples						2.23	3.15	
NOAA Buoy 42036	10/2150	1009.5	11/0450	29	35			
Pensacola						2.87	4.34	
Pulaski Shoal Light (PLSF1)	09/2200	1001.1	09/2210	51	65			
Saint Petersburg						1.80	4.20	
Sand Key Light (SANF1)	09/2000	1004.5	09/1610	55	76			
Sombrero Key Light (SMKF1)	09/1000	1004.5	09/0310	48	61	0.50	1.70	
Turkey Point (XTKY)			09/1455	25[e]	37			
Vaca Key NOS (VCAF1)	09/0836	1005.8	09/0142	26	39	1.00	1.20	
Virginia Key (KVIK)			09/1347	36	44	1.15	1.86	
Alabama								
Marine								
Bayou La Batre						3.93	5.43	
Dauphin Island (DPIA1)	12/2205	1011.0	11/1550	37	56	3.12	4.50	
Fort Morgan						6.25	7.75	
Mobile						2.98	4.48	
Mobile Coast Guard Sector						2.82	5.25	
Mobile State Docks						3.20	4.83	
NOAA Buoy 42040	11/2050	1006.0	11/1150	34	47			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Mississippi								
ICAO Sites								
Biloxi (KBIX)	12/1018	1010.4	12/1138	28	39			
Gulfport (KGPT)	12/2122	1009.1	12/1236	32	42			0.03
Pascagoula (KPQL)	12/2206	1010.8	11/1621	24	34			0.12
Marine								
Bay - Waveland Yacht Club						5.81	7.62	
Gulfport						2.58	4.51	
Pascagoula NOAA						3.89	5.34	
Louisiana								
ICAO Sites								
Abbeville (K0R3)	12/2200	999.7	13/0700	30	48			
Acadiana (KARA)[i]	13/2156	1000.3	13/1605	31	42			
Alexandria (KAEX)[i]	13/1146	1000.7	13/1528	33	43			2.17
Alexandria - Esler (KESF)	13/1334	1002.0	13/1624	27	39			1.85
Barksdale AFB (KBAD)	13/2210	994.6	13/2130	34	44			1.63
Baton Rouge (KBTR)	12/2130	1003.7	12/1132	31	45			
Belle Chasse NAS (KNBG)	12/2252	1006.5	12/1149	30	46			
De Ridder (KDRI)	13/1101	996.5	13/1200	29	45			
Fort Polk (KPOE)	13/1240	997.3	13/1319	34	49			
Fort Polk (KDNK)	13/1303	997.6	13/1922	29	43			
Galliano (KGAO)[i]			11/2102	28	38			
Hammond (KHDC)			12/1116	32	42			
Houma (KHUM)[i]			12/1850	31	44			
Lafayette (KLFT)	13/2242	1000.7	13/1437	26	42			2.21
Lake Charles - Chennault (KCWF)[i]	13/0600	997.7	13/0600	36	42			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Lake Charles (KLCH)	13/0642	995.3	13/0842	46	67			1.93
Monroe (KMLU)	13/2237	1002.4	14/0237	26	35			1.39
New Orleans Intl Airport (KMSY)	12/2244	1005.8	12/1217	35	50			1.55
New Orleans Lakefront (KNEW)	12/2302	1006.1	12/1045	44	60			1.28
Oakdale (KACP)	13/1000	999.9	13/1900	22	37			
Patterson (KPTN)[i]	12/2155	1002.1	13/1055	26	38			
Salt Point (KP92)[i]	12/1253	1002.4	12/1453	21	36			
Shreveport Downtown (KDTN)	13/2153	994.0	13/2253	30	48			
Shreveport (KSHV)	13/2202	992.9	13/2316	33	49			1.09
Slidell (KASD)	12/2149	1007.5	12/1925	25	39			
Sulphur (KUXL)[i]	13/0758	994.6	13/0720	34	54			
RAWS[f]								
Caney (CANL1)			13/2258		38			0.62
Gum Springs (GUML1)			13/1809		38			2.26
Hackberry (HCKL1)[i]			13/0400	42	60			2.63
Holmwood (CLCL1)			13/0700	40	58			3.93
Lacassine (LACL1)			13/1100	33	49			3.30
LAIS[j]								
Alexandria (ALDL1)			13/1500		46			4.18
Crowley (CRRL1)			13/1300		45			
Jeanerette (JNRL1)			12/2100		45			1.78
Lake Charles (LCPL1)			13/1000		55			2.59
Port Barre (RDRL1)			13/1600		40			2.30
Rosepine (RPRL1)			13/1400		49			1.72
Other								
Arcadia					52			
Bellwood								5.50
Benton					45			
Caillou Lake USGS (DCLL1)[i]			12/2030		48			
Natchitoches					54			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Marine								
Amerada Pass (AMRL1)	12/2100	999.2	12/1424	35	49	6.75	8.02	
Barataria – Lafitte						4.70	5.11	
Bayou Bienvenue						7.70	8.16	
Bayou Dupre						6.90	7.44	
Bayou Grand Caillou						7.00	7.45	
Caillou Lake SW						7.30	7.80	
Calcasieu Pass (CAPL1)	13/0936	989.5	13/0818	61	75	9.80	11.80	
Freshwater Canal Locks (8766072)						9.91	10.08	
Grand Isle (GISL1)	12/2030	1006.4	12/1730	29	45	3.85	5.22	
Lake Pontchartrain – Mid-Lake (MDLL1)			12/1010	37	49	5.70	6.02	
Lake Pontchartrain – Rigolets						3.80	4.24	
Lake Pontchartrain – West End						5.00	5.40	
Mandeville						5.80	6.19	
Marsh Island (MRSL1)	12/2200	995.5	12/1800	47	64			
NOAA Buoy 42007	11/2050	1008.3	12/1120	31	41			
Port Fourchon						4.17	5.58	
Shell Beach (SHBL1)	12/0948	1005.5	12/1012	23	30	6.51	7.80	
Southwest Pass – Pilot's Station E (PSTL1)	12/0924	1004.6	12/0630	48	53	3.16	4.71	
Tesoro Marine Terminal (8764044)						4.31	4.64	
Texas								
ICAO Sites								
Angleton / Brazoria (KLBX)[i]	13/0753	974.6	12/2353	32	49			
Bay City (KBYY)	13/0625	985.8	13/0625	33	46			
Beaumont (KBPT)	13/0905	982.4	13/0814	61	83			5.45
Brenham (K11R)	13/1148	987.5	13/1212	33	44			
College Station (KCLL)	13/1338	985.8	13/1153	30	43			3.45

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Conroe (KCXO)[i]	13/1153	962.4	13/1002	36	52			
Corsicana (KCRS)	13/1845	987.8	13/1543	34	44			1.56
Galveston (KGLS)[i]	13/1652	1002.3	13/1652	24	33			
Houston / Bush (KIAH)	13/1011	961.1	13/0951	49	57			
Houston / D.W. Hooks (KDWH)[i]	13/1053	967.5	13/0840	28	47			
Houston / Hobby (KHOU)[i]	13/0853	960.0	13/1102	65	80			
Huntsville (KUTS)	13/1344	968.2	13/1316	29	50			4.90
Longview (KGGG)[i]	13/2053	984.1	13/2009	32	49			
Lufkin (KLFK)[i]	13/1353	982.5	13/1239	34	60			2.59[e]
Orange (KORG)[i]	13/0326	994.6	13/0326	34	44			
Palacios (KPSX)	13/0753	991.2	12/2353	30	43			
Palestine (KPSN)[i]	13/1328	991.2	13/1308	23	34			
Paris (KPRX)	13/2355	988.5	14/0015	25	35			2.17
Pearland (KLVJ)[i]	13/0453	982.4	13/0419	37	56			
Port Lavaca (KPKV)	13/0826	993.9	13/0326	29	36			
Sugarland (KSGR)[i]	13/0353	991.2	13/0353	37	47			
Sulphur Springs (KSLR)	13/2227	987.5	13/2347	28	35			
Terrell (KTRL)	13/2103	989.2	13/1733	29	39			1.82
Tyler (KTYR)	13/2053	976.9	13/2007	28	40			2.69
Victoria (KVCT)	13/0847	993.9	13/0720	25	34			
Wharton (KARM)	13/0840	987.5	13/0840	34	44			
RAWS[f]								
Anahuac (TR474)[i]			13/0559	47	63			
Attwater NWR (ANWT2)			13/0956	28	40			
Brazoria NWR (BZRT2)			13/0809	34	62			
Buna (KRBT2)			13/1400	28	56			6.62
Conroe (CKNT2)			13/1503	20	49			
Coldsprings (CPGT2)			13/1002	13	41			
Dayton (TR968)			13/1207	45	68			11.88
Henderson (HDRT2)			13/2106		49			2.05
Linden (DENT2)			14/0005		35			2.17

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Lufkin (LRWT2)			13/1603		42			2.59
Sabine Pass (FADT2)[i]			12/2300	34	44			0.10
Sabine South (SSRT2)			13/1907		36			4.19
San Bernard (SRDT2)			13/0807	28	49			
Texarkana (TEXT2)			14/0104		35			2.45
Warren (WRRT2)			13/1500	21	46			5.40
Woodville (WVLT2)			13/1400	30	59			7.11
AWS[k]								
Brenham (BRENH)	13/1029	988.1	13/0959	17	38			
Damon (DAMON)[i]	13/0814	978.0	13/0659	30	56			
Freeport (FRPAL)	13/0644	971.6	13/0659	42	66			
Galveston (GLVST)[i]	12/2114	993.9	12/2114	40	57			
Houston (HSSLS)[i]	13/0544	988.1	13/0444	16	41			
Houston (HSTN0)[i]	13/0643	985.8	13/0614	21	35			
Livingston (LVING)[i]	13/1028	979.0	13/1014	23	44			
Prairie View (PRRV2)	13/1114	980.4	13/1214	23	48			
Spring (TWOOD)	13/0928	974.6	12/1814	6	38			
TBCD[l]								
Anahuac (2150)	13/0745	962.8	13/1026	52	73			7.16
Anahuac (2550)[i]	13/0448	978.7	13/0448	51	52			1.68
Baytown (7050)	13/0726	962.8	13/0745	28	44			6.84
Baytown (7150)	13/0821	962.8	13/0753	52	62			
Baytown (7151)								8.20
Hankamer (6050)	13/0856	962.8	13/0928	67	73			5.64
Winnie (5250)	13/0609	972.2	13/0820	39	50			8.28
TCOON[m]								
Port Arthur (8770475)			13/0654	47	73	11.25	11.93	
Rainbow Bridge (8770520)						9.29	9.69	
Sabine Pass (8770570)						12.54	14.24	
Texas Point (8770520)[i]			13/0406	57	80	11.79	13.37	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
TTUHRT[n]								
Anahuac (0103A)	13/0923	955.4	13/0746	59	74			
Beaumont 5 SW (0108B)	13/0855	977.3	13/1106	53	66			
China 5 ESE (0111A)	13/0937	975.7	13/1033	58	73			
Danbury (0220B)	13/0743	965.3	13/0650	54	66			
Devers (0218B)	13/0909	957.2	13/0910	59	72			
Fannett 2 N (0107A)	13/0903	971.4	13/0708	52	64			
Felicia (0112A)	13/0936	968.0	13/1045	55	67			
Hamshire 2 S (0105A)	13/0925	965.7	13/0830	56	73			
Hankamer (0104B)	13/0828	960.6	13/0710	69	83			
Hankamer (0216B)	13/0901	957.1	13/0718	64	95			
Hankamer (0217A)	13/0907	964.2	13/0837	55	76			
Hankamer (0222B)	13/0912	960.2	13/0901	62	78			
Hankamer (0224B)	13/0903	956.8	13/0800	53	68			
Liverpool (0214B)	13/0745	956.3	13/0639	53	69			
Nome 6 SSE (0106B)	13/0847	967.0	13/0829	59	72			
Port Bolivar (0110A)	13/0759	950.7	13/1016	64	76			
Raywood (0109A)	13/0942	958.7	13/1123	61	82			
Winnie (0102B)	13/0833	963.7	13/0844	55	73			
Winnie (0213A)[i]	13/0940	965.6	13/0752	71	80			
Winnie (0223A)	13/0908	964.2	13/0859	55	70			
Other								
Addicks (BAKT2)[i]								7.97
Addicks (LLYT2)								9.90
Aldine (HGBT2)[i]								7.28
Barrett (SHLT2)[i]								6.42
Beaumont (BEAT2)[i]								10.50
Beaumont (JYTT2)								5.16
Beaumont (JYUT2)								5.55
Beaumont (JYVT2)								12.56
Beaumont (JYWT2)								5.87

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Beaumont (JZET2)								6.70
Beaumont (JZFT2)								7.44
Beaumont (JZGT2)								8.94
Beaumont (JZHT2)								6.66
Beaumont (JZIT2)								7.60
Beaumont (JZKT2)								6.58
Beaumont (JZLT2)								7.08
Beaumont (JZMT2)								9.96
Beaumont (JZRT2)								7.52
Bevil Oaks (JTWT2)								7.12
Bevil Oaks (JYNT2)								6.61
Bevil Oaks (JYOT2)								7.68
Bevil Oaks (JZCT2)								7.05
Bevil Oaks (JZDT2)								6.46
Bunker Hill Village (WSBT2)								10.10
Dickinson (DCKNW)[i]	13/0829	954.3	13/0944	43	64			
Central Gardens (JZJT2)								8.94
China (JYQT2)								8.39
China (JZST2)								8.59
China (JZUT2)								8.82
Clear Lake Shores (CLCT2)								6.32
Cleveland (CPGT2)[i]								5.94
Cypress (LKLT2)								8.70
Fannett (JZPT2)								6.30
Fannett (JZQT2)								5.71
Fannett (JZXT2)								6.06
Friendswood (FNDT2)								10.47
Gary City					74			
Groveton (WDLT2)[i]								5.42
Hamshire (JYST2)								7.41
Hillcrest (ALVT2)								12.02

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Hilshire Village (DEHT2)								11.01
Hockley (KHOT2)								5.66
Hooks Apt. (KYKT2)[i]								7.05
Hooks Apt. (STUT2)								10.67
Houston (BBST2)								12.40
Houston (BKHT2)								12.13
Houston (BSFT2)								10.82
Houston (C9180)	13/0928	967.8	13/0928	51	83			
Houston (ELBT2)								17.59
Houston (HABT2)[i]								5.00
Houston (HBMT2)								10.44
Houston (HTGT2)[i]								10.16
Houston (MGOT2)								10.31
Houston (MRFT2)								11.22
Houston (RLPT2)								8.85
Houston (SMWT2)								10.67
Houston (VGBT2)								12.83
Houston (WSHT2)[i]								5.78
Humble (HMMT2)								10.79
Jacksonville					53			
Jersey Village (FHNT2)								11.14
Jersey Village (JVLT2)								8.86
Jersey Village (SUMT2)								9.14
Katy (BBKT2)								7.65
Katy (SMAT2)[i]								7.76
Livingston (LIVT2)								8.17
Lumberton (LLBT2)								7.37
Lumberton			13/0955		72			
Meyerland (WWHT2)								8.82
Nederland			13/0727		89			
Nome (JZAT2)								8.03

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Nome (JZBT2)								9.37
Nome (JZWT2)								10.63
North Cleveland (CVLT2)[i]								6.90
North Cleveland (CLDT2)[i]								7.47
Port Arthur (JYHT2)								8.15
Port Arthur			13/0925		92			
San Leon (MOKT2)								13.92
Saratoga			13/1013		77			
Shenandoah (CFKT2)[i]								9.43
Shenandoah (CKNT2)								14.46
Sour Lake (JYMT2)								6.62
South Houston (BFOT2)[i]								8.31
Spring Valley (BSBT2)[i]								9.68
Stagecoach (HEGT2)								8.54
Sugar Land (SGLT2)								5.75
The Woodlands (PBST2)								11.71
The Woodlands (PGRT2)[i]								6.01
Thicket (JYLT2)								8.11
Town West (SGRT2)								5.75
Westbury (HWET2)[i]								8.25
Wildwood (WWDT2)								6.99
Winnie (GTOT2)[i]								10.47
Marine								
Battleship Texas SP (NP114)[i]						6.11	7.89	
Bob Hall Pier						3.84	5.39	
Copano Bay						2.86	3.41	
Eagle Point (EGPT2)						10.75	11.95	
Eagle Point (EPPT2)	13/0748	954.3	13/0606	59	78			
Entrance to Clear Lake (CLLT2)[i]						7.95	8.19	
Freeport (FCGT2)						6.25	7.42	
Freeport (FPPT2)			13/0524	51	76			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Galveston Bay Entrance (GNJT2)[i]						9.41	9.75	
Galveston Pleasure Pier (GPST2)	13/0754	951.7	13/0448	52	76	10.80	12.25	
Galveston Ship Channel North Jetty (GSJT2)			13/0218	51	67			
Ingleside						3.20	3.83	
Manchester (TX035)						11.74	12.30	
Morgan Point (MGPT2)[i]			13/0612	46	69	7.76	9.01	
NOAA Buoy 42019	13/0150	984.9	13/0150	42	56			
NOAA Buoy 42035	13/0450	952.1	13/0850	54	74			
Packery Channel						2.89	3.27	
Port Aransas						3.39	4.51	
Port Aransas							5.37	
Port Lavaca						2.92	3.86	
Port O'Connor						3.53	4.24	
Port of Galveston Pier 21 (GTOT2)						10.25	11.38	
Rockport						2.40	2.79	
Rollover Pass (ROLT2)[i]						11.06	11.23	
Sabine (SRST2)[i]	13/0600	977.5	13/0600	65	86			
Sabine Pass North (SBPT2)	13/0718	983.8	13/0548	61	83			
Seadrift						2.77	3.26	
Texas State Aquarium						3.08	3.71	
White Point						2.68	3.44	
Arkansas								
ICAO Sites								
Arkadelphia (KM89)	14/0324	994.8	14/0440	24	37			
Camden (KCDH)	14/0320	997.9	14/0020	23	49			
De Queen (KDEQ)	14/0216	982.7	14/0522	25	34			1.91
El Dorado (KELD)	13/2339	996.9	13/1819	23	41			1.63

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Hot Springs (KHOT)	14/0453	992.2	14/0343	25	43			1.58
Little Rock (KLIT)	14/0653	996.2	14/0333	28	40			0.96
Little Rock AFB (KLRF)	14/0520	996.6	14/0934	27	36			1.39
Pine Bluff (KPBF)	14/0653	994.4	14/0253	26	40			0.92
Stuttgart (KSGT)	14/0715	998.5	14/0915	33	42			
Texarkana (KTXK)[i]	14/0053	988.2	14/0037	34	49			1.29
Other								
Nashville					62			
Saratoga					54			
Offshore								
NOAA Buoy 41046 – East of Bahamas	06/1950	1011.4	07/1228	36	43			
NOAA Buoy 42001 – Central Gulf of Mexico	11/2050	959.7	12/0240	59	76			
Shell Platform Auger (42361)[o,i]	12/1145	966.8	12/1145	109				
TABS Buoy 42047	12/2130	956.6	12/2330	50	66			

[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 ASOS reports are 2 min; buoy averaging periods are 8 min.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).
[e] Estimated
[f] Remote Automated Weather Station
[g] Citizen Weather Observer Program
[h] South Florida Water Management District
[i] Incomplete data
[j] Louisiana Agriclimate Information System
[k] Automatic Weather Station
[l] Trinity Bay Conservation District
[m] Texas Coastal Ocean Observation Network
[n] Texas Tech University Hurricane Research Team
[o] Anemometer height 122 meters

Table 4. Track forecast evaluation (heterogeneous sample) for Hurricane Ike, 1 – 14 September 2008. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	35 (51)	80 (49)	128 (47)	181 (45)	324 (41)	513 (37)	774 (33)
GFNI	27 (46)	48 (43)	66 (41)	78 (39)	114 (35)	166 (32)	205 (28)
GFDI	21 (51)	**31 (49)**	**44 (47)**	61 (45)	98 (41)	134 (36)	172 (32)
HWFI	20 (51)	34 (49)	49 (47)	68 (45)	106 (41)	125 (35)	188 (31)
GFSI	29 (51)	53 (49)	77 (47)	100 (45)	141 (41)	169 (37)	225 (33)
AEMI	25 (51)	47 (49)	68 (47)	88 (44)	120 (31)	**117 (23)**	179 (18)
NGPI	24 (50)	46 (48)	67 (46)	86 (44)	117 (40)	175 (36)	250 (32)
UKMI	27 (48)	51 (46)	75 (44)	94 (42)	128 (38)	185 (35)	253 (29)
EGRI	26 (49)	49 (47)	75 (45)	98 (43)	128 (39)	184 (33)	265 (29)
EMXI	19 (44)	**29 (42)**	**37 (41)**	**45 (39)**	**73 (35)**	**95 (32)**	**123 (29)**
BAMD	24 (51)	46 (49)	74 (47)	103 (45)	166 (41)	243 (37)	332 (33)
BAMM	26 (50)	46 (48)	69 (46)	96 (44)	150 (40)	193 (36)	243 (32)
BAMS	49 (48)	86 (46)	120 (44)	153 (43)	196 (39)	215 (35)	228 (32)
LBAR	22 (48)	46 (46)	69 (44)	93 (43)	131 (39)	131 (35)	186 (25)
TVCN	20 (51)	33 (49)	48 (47)	59 (45)	**86 (41)**	122 (37)	**163 (33)**
GUNA	21 (48)	37 (46)	56 (44)	71 (42)	98 (38)	132 (32)	195 (28)
FSSE	20 (49)	34 (47)	47 (45)	61 (43)	94 (39)	131 (35)	174 (31)
OFCL	17 (50)	32 (48)	46 (46)	59 (44)	91 (40)	121 (36)	166 (32)
NHC Official (2003-2007 mean)	34.0 (1742)	58.2 (1574)	82.2 (1407)	106.2 (1254)	154.2 (996)	207.5 (787)	272.5 (627)

Table 5. Intensity forecast evaluation (heterogeneous sample) for Hurricane Ike, 1 – 14 September 2008. Forecast errors (kt) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
OCD5	8.6 (51)	12.3 (49)	16.4 (47)	17.6 (45)	23.3 (41)	27.9 (37)	27.4 (33)
GHMI	9.1 (51)	14.5 (49)	19.1 (47)	19.6 (45)	17.9 (41)	**14.8 (36)**	**15.9 (32)**
HWFI	9.1 (51)	13.5 (49)	18.5 (47)	19.5 (45)	24.6 (41)	24.2 (35)	25.5 (31)
LGEM	8.1 (51)	11.4 (49)	15.1 (47)	14.8 (45)	21.3 (41)	24.2 (37)	**22.0 (33)**
DSHP	8.8 (51)	12.6 (49)	17.1 (47)	18.2 (45)	28.3 (41)	34.0 (37)	32.8 (33)
FSSE	7.9 (49)	11.4 (47)	13.7 (45)	16.0 (43)	**14.4 (39)**	**13.7 (35)**	**16.4 (31)**
ICON	**7.6 (51)**	**10.2 (49)**	13.6 (47)	**13.7 (45)**	**15.6 (41)**	**14.3 (35)**	**18.2 (31)**
OFCL	7.8 (50)	10.9 (48)	13.3 (46)	14.3 (44)	17.5 (40)	18.3 (36)	23.8 (32)
NHC Official (2003-2007 mean)	6.7 (1742)	10.0 (1574)	12.3 (1407)	14.3 (1254)	18.2 (996)	19.7 (787)	21.8 (627)

Table 6. Watch and warning summary for Hurricane Ike, 1 – 14 September 2008.

Date/Time (UTC)	Action	Location
5 / 1800	Hurricane Watch issued	Southeastern Bahamas / Turks and Caicos
6 / 0300	Hurricane Watch upgraded to Hurricane Warning	Southeastern Bahamas / Turks and Caicos
6 / 0300	Hurricane Watch issued	Central Bahamas
6 / 0600	Tropical Storm Warning issued	Cabo Frances Viejo, Dominican Republic to Gonaives, Haiti
6 / 1500	Hurricane Watch issued	Guantanamo to Camaguey
6 / 2100	Hurricane Warning modified to	Southeastern and Central Bahamas / Turks and Caicos
6 / 2100	Hurricane Watch upgraded to Hurricane Warning	Guantanamo to Holguin and Santiago de Cuba
6 / 2100	Hurricane Watch modified to	Granma to Camaguey
7 / 0300	Hurricane Warning modified to	Guantanamo to Las Tunas
7 / 0300	Hurricane Watch modified to	Camaguey to Sancti Spiritus
7 / 0900	Hurricane Warning modified to	Guantanamo to Ciego de Avila
7 / 0900	Hurricane Watch modified to	Sancti Spiritus to Villa Clara and Cienfuegos
7 / 0900	Hurricane Watch issued	Andros Island
7 / 1200	Tropical Storm Watch issued	Cayman Islands
7 / 1500	Hurricane Warning modified to	Guantanamo to Villa Clara and Cienfuegos
7 / 1500	Hurricane Watch issued	Matanzas to La Habana
7 / 1500	Hurricane Watch issued	Ocean Reef to Dry Tortugas
7 / 1500	Tropical Storm Warning discontinued	Cabo Frances Viejo to Dominican Republic / Haiti border
7 / 1500	Tropical Storm Warning modified to	Dominican Republic / Haiti border to Gonaives
7 / 2100	Hurricane Warning modified to	Guantanamo to Matanzas
7 / 2100	Hurricane Watch modified to	La Habana to Pinar del Rio and Isle of Youth
7 / 2100	Tropical Storm Warning issued	Andros Island
7 / 2100	Tropical Storm Watch issued	Jamaica
8 / 0300	Tropical Storm Warning discontinued	Dominican Republic / Haiti border to Gonaives
8 /0600	Hurricane Warning discontinued	Southeastern and Central Bahamas / Turks and Caicos
8 / 0600	Tropical Storm Warning modified to	Central Bahamas, Andros Island, Southeastern Bahamas excluding Inaguas and Mayaguana
8 / 0900	Tropical Storm Warning issued	Ocean Reef to Dry Tortugas
8 / 0900	Hurricane Watch discontinued	Andros Island
8 / 0900	Tropical Storm Warning discontinued	Southeastern and Central Bahamas, excluding Ragged Island

Date/Time (UTC)	Action	Location
8 / 0900	Tropical Storm Warning modified to	Andros and Ragged Islands
8 / 0900	Tropical Storm Warning issued	La Habana to Pinar del Rio and Isle of Youth
8 / 1500	Tropical Storm Warning and Hurricane Watch discontinued	La Habana to Pinar del Rio and Isle of Youth
8 / 1500	Hurricane Warning modified to	Guantanamo to Pinar del Rio and Isle of Youth
8 / 1500	Tropical Storm Warning issued	Little Cayman and Cayman Brac
8 / 1500	Tropical Storm Watch modified to	Grand Cayman
8 / 1800	Tropical Storm Watch discontinued	Jamaica
8 / 2100	Hurricane Watch discontinued	Ocean Reef to Dry Tortugas
8 / 2100	Tropical Storm Warning discontinued	Andros and Ragged Islands
9 / 0000	Hurricane Warning discontinued	Guantanamo to Camaguey
9 / 0000	Hurricane Warning modified to	Ciego de Avila to Pinar del Rio and Isle of Youth
9 / 0900	Hurricane Warning discontinued	Ciego de Avila to Villa Clara and Cienfuegos
9 / 0900	Hurricane Warning modified to	Matanzas to Pinar del Rio and Isle of Youth
9 / 1200	Tropical Storm Warning discontinued	Little Cayman and Cayman Brac
9 / 1200	Tropical Storm Watch discontinued	Grand Cayman
10 / 0300	Tropical Storm Warning discontinued	Ocean Reef to Seven Mile Bridge
10 / 0300	Tropical Storm Warning modified to	Seven Mile Bridge to Dry Tortugas
10 / 0300	Hurricane Warning downgraded to Tropical Storm Warning	Matanzas to Pinar del Rio and Isle of Youth
10 / 0900	Tropical Storm Warning discontinued	Seven Mile Bridge to Key West
10 / 0900	Tropical Storm Warning modified to	Key West to Dry Tortugas
10 / 1800	Tropical Storm Warning discontinued	Matanzas to Pinar del Rio and Isle of Youth
10 / 2100	Tropical Storm Warning issued	Mississippi River to Cameron
10 / 2100	Hurricane Watch issued	Cameron to Port Mansfield
11 / 0300	Tropical Storm Warning discontinued	Key West to Dry Tortugas
11 / 0900	Tropical Storm Warning modified to	Alabama / Mississippi border to Cameron
11 / 1500	Hurricane Warning issued	Morgan City to Baffin Bay
11 / 1500	Tropical Storm Warning modified to	Alabama / Mississippi border to Morgan City
11 / 1500	Tropical Storm Warning issued	Baffin Bay to Port Mansfield
11 / 1500	Hurricane Watch modified to	Baffin Bay to Port Mansfield
12 / 0300	Hurricane Watch changed to Tropical Storm Warning	Baffin Bay to Port Mansfield
12 / 1800	Hurricane Warning modified to	Morgan City to Port Aransas
12 / 1800	Tropical Storm Warning modified to	Port Aransas to Port Mansfield

Date/Time (UTC)	Action	Location
13 / 0700	Tropical Storm Warning discontinued	Port Aransas to Port Mansfield
13 / 0900	Hurricane Warning modified to	Morgan City to Port O'Connor
13 / 0900	Tropical Storm Warning discontinued	Alabama / Mississippi border to Morgan City
13 / 1500	Hurricane Warning discontinued	Morgan City to Port O'Connor
13 / 1500	Tropical Storm Warning issued	Morgan City to Sargent
13 / 2100	Tropical Storm Warning discontinued	Morgan City to Sargent

Table 7. Selected maximum wind gusts due to the post-tropical remnants of Hurricane Ike, 1 – 14 September 2008.

Location	Maximum Wind Gust (kt)	Location	Maximum Wind Gust (kt)
Missouri		**Ohio (continued)**	
Poplar Bluff (KPOF)	57	Cleveland – Lakefront (KBKL)	55
		Columbus (KCMH)	65
Illinois		Dayton International Apt. (KDAY)	52
Carbondale (KMDH)	53	Dayton Wright Brothers Apt. (KMGY)	59
		Findlay (KFDY)	56
Indiana		Lorain (KLPR)	62
Evansville (KEVV)	56	Marion (KMNN)	56
Huntingburg (KHNB)	58	OSU Aiport (KOSU)	55
Indianapolis (KIND)	55	Rickenbacker (KLCK)	60
		Wilmington (KILN)	64
Kentucky		Youngstown (KYNG)	53
Cincinnati – N Kentucky Int'l Apt. (KCVG)	64		
Fort Knox (KFTK)	56	**Pennsylvania**	
Lexington (KLEX)	52	Beaver Falls (KBVI)	60
Louisville (KSDF)	65	Du Bois (KDUJ)	53
Owensboro (KOWB)	55		
		Ontario, Canada	
Ohio		Long Point (CWPS)	55
Bolton Field (KTZR)	60	Point Petre (CWQP)	52
Cincinnati (KLUK)	53	Port Colborne (CWPC)	57

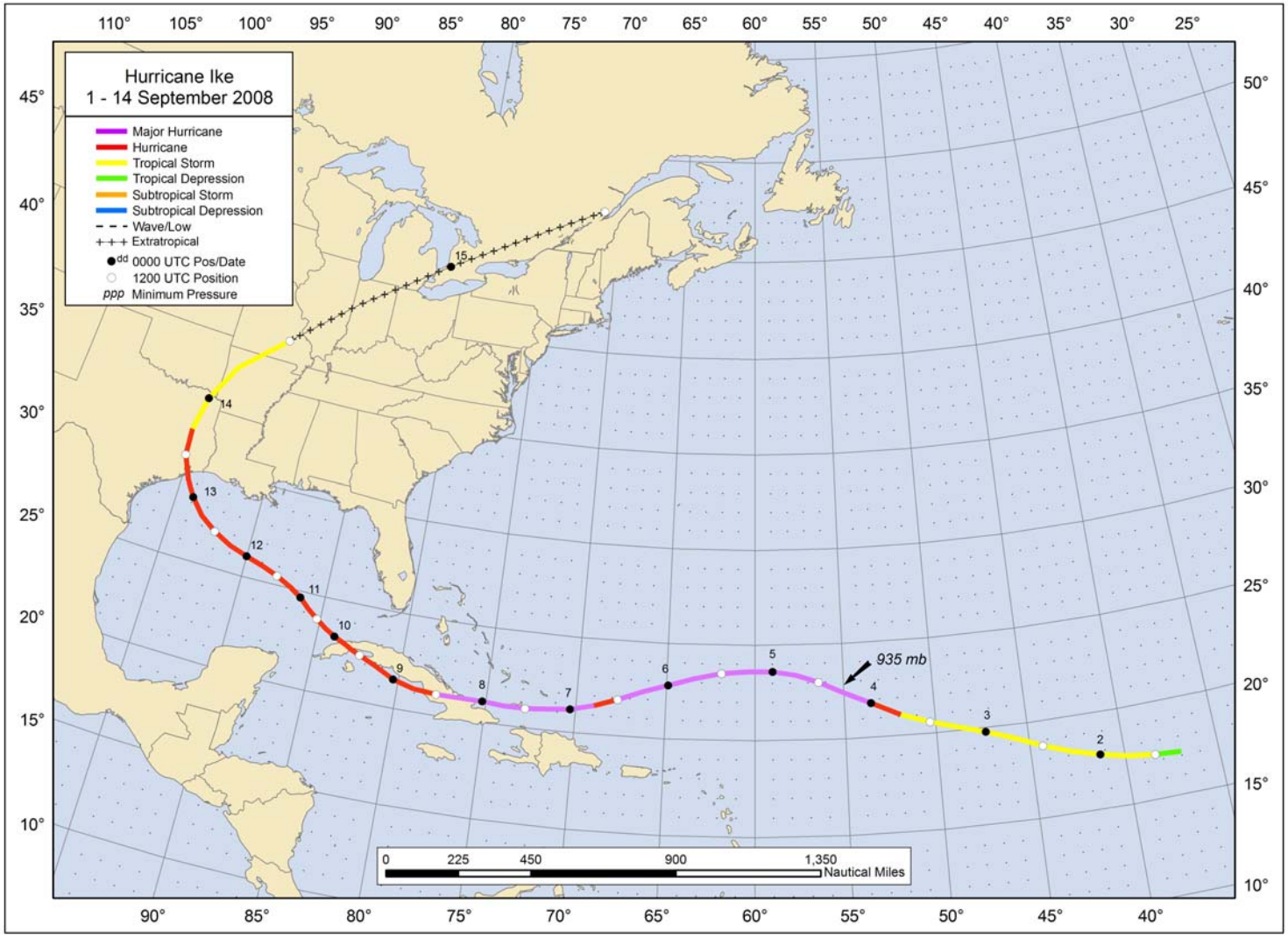


Figure 1. Best track positions for Hurricane Ike, 1 – 14 September 2008. Track during the extratropical stage is based on analyses from the NOAA Hydrometeorological Prediction Center and Environment Canada.

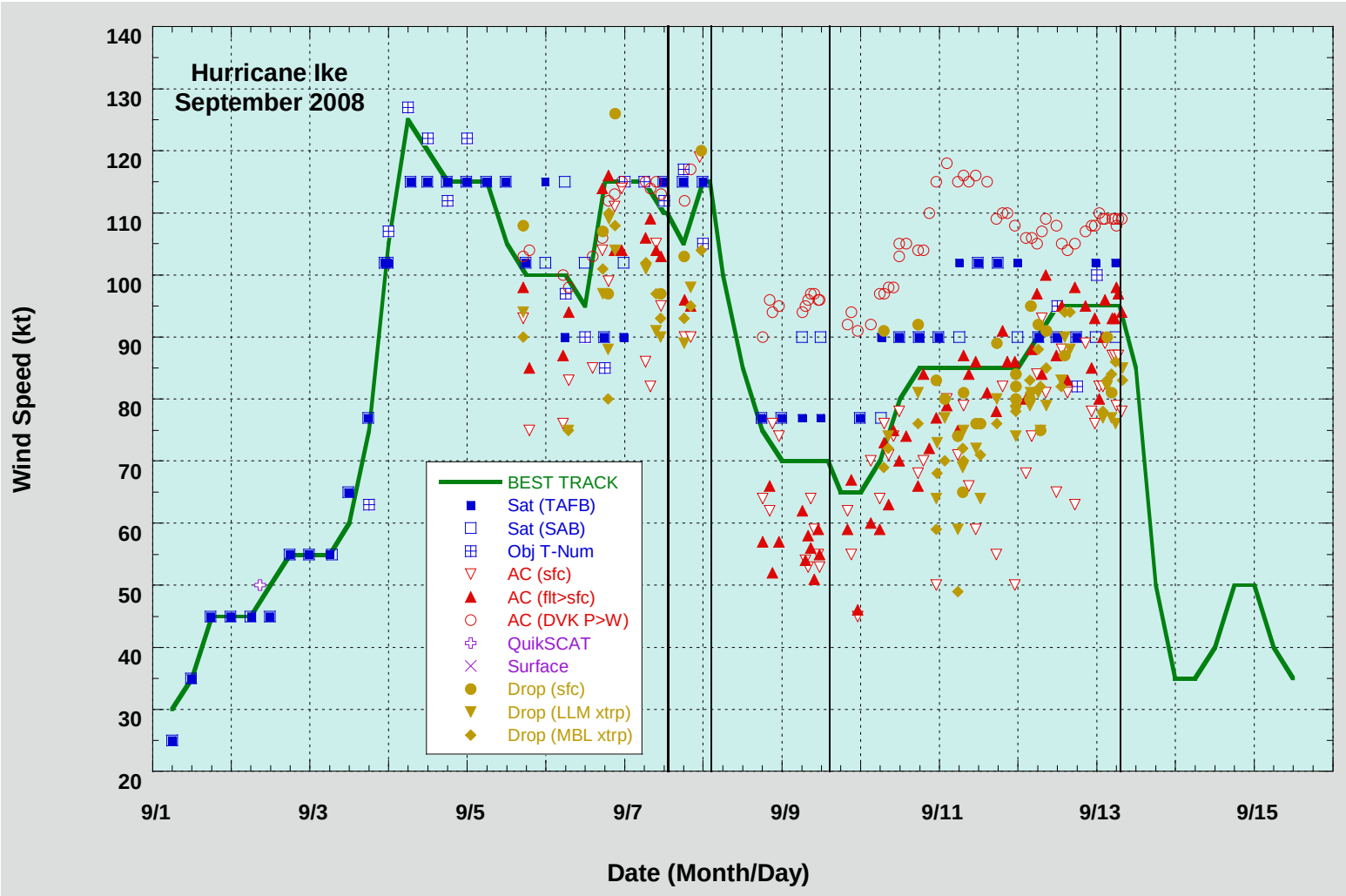


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Ike, 1 – 14 September 2008. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde 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), and from the sounding boundary layer mean (MBL). Objective Dvorak estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC. Solid vertical lines correspond to landfalls.

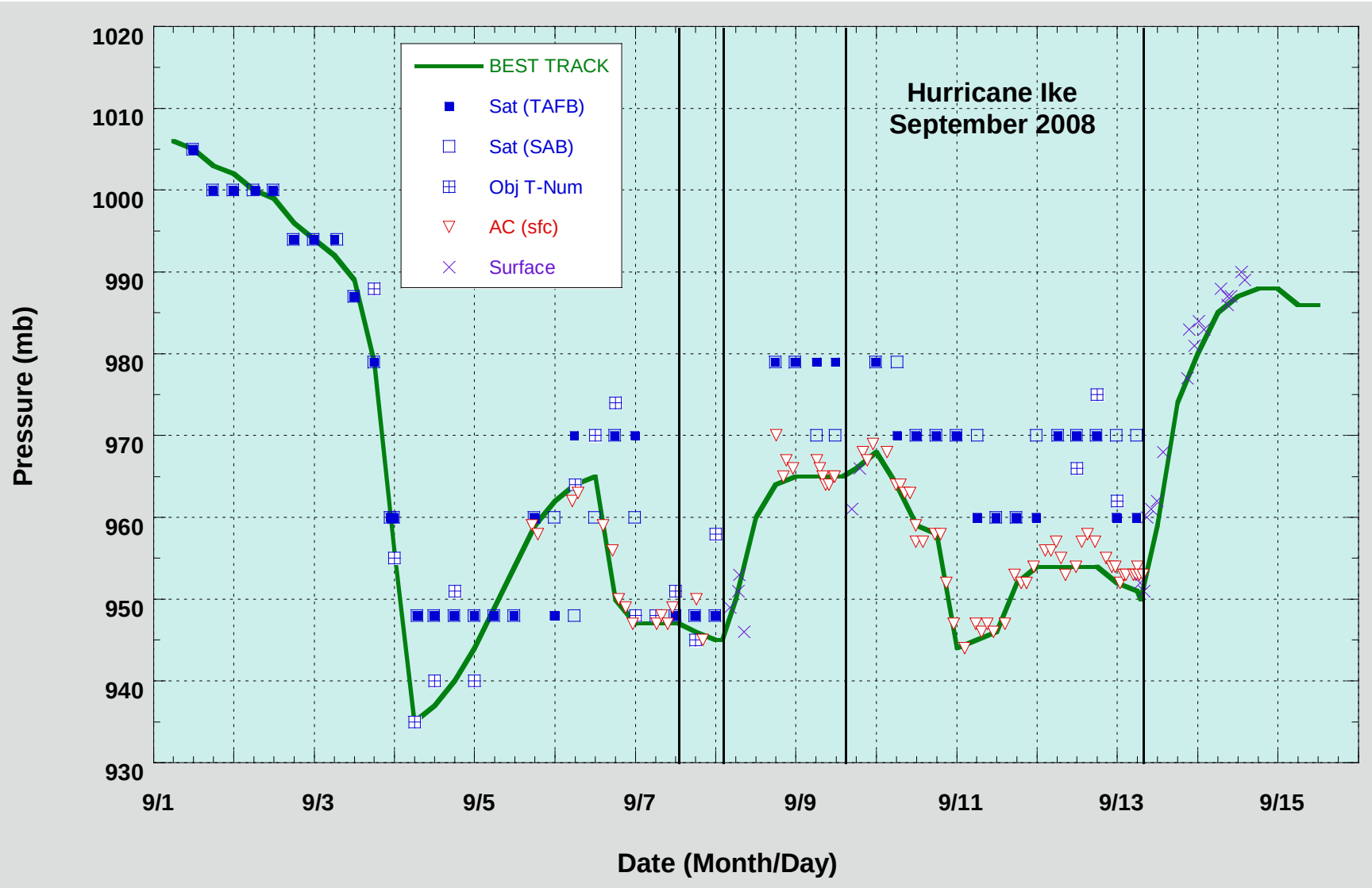


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Ike, 1 – 14 September 2008. Objective Dvorak estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC. Solid vertical lines correspond to landfalls.

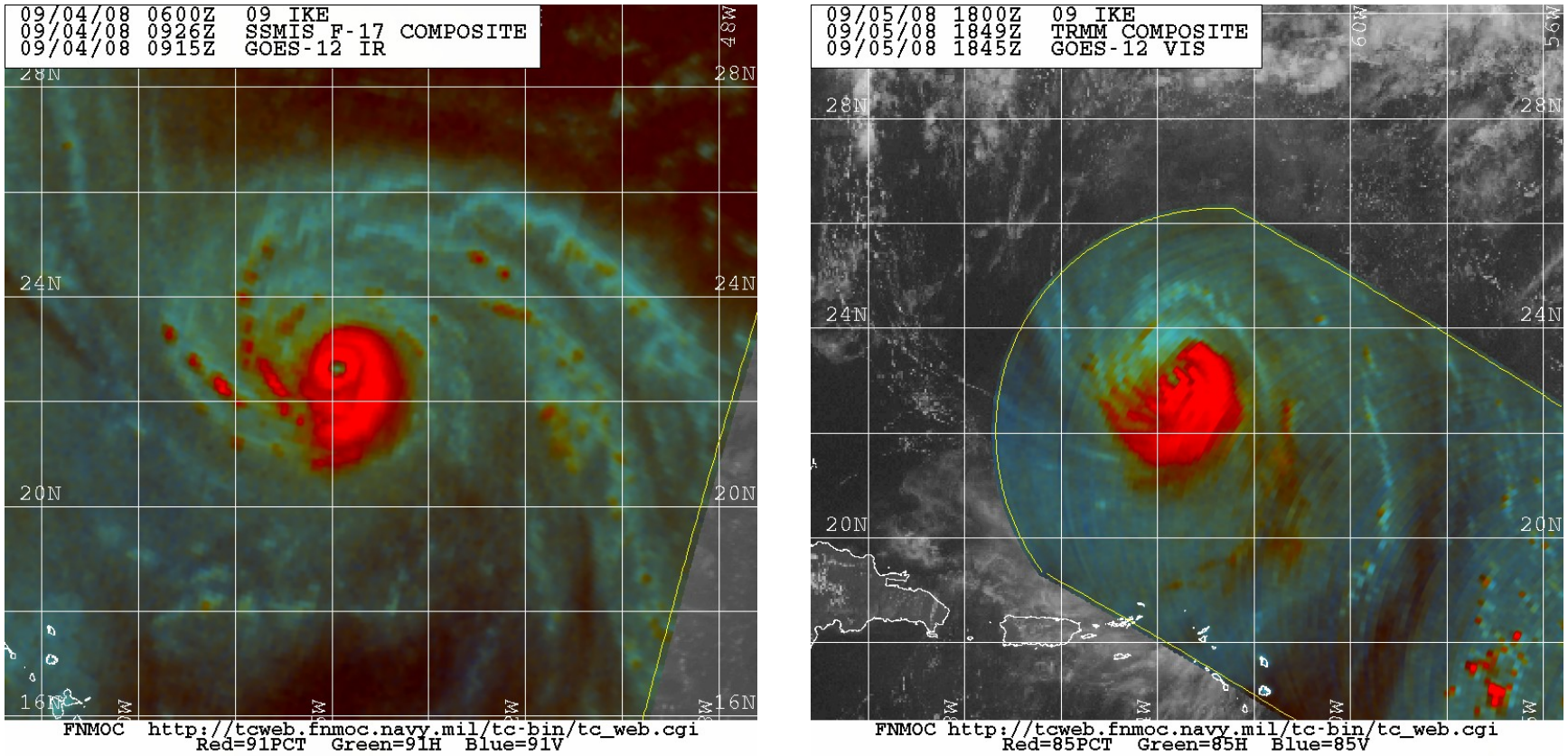


Figure 4. A comparison of microwave imagery for Hurricane Ike near the time of its peak intensity (left) and after it had endured several days of northerly and northeasterly shear. The left image is a 91 GHz SSMIS image at 0926 UTC 4 September, and the right image is an 85 GHz TRMM image at 1849 UTC 5 September. Note in the right image that an eye is still present despite the strong northerly shear that has completely eroded the deep convection in the northern eyewall. Image courtesy of the Fleet Numerical Meteorology and Oceanography Center.

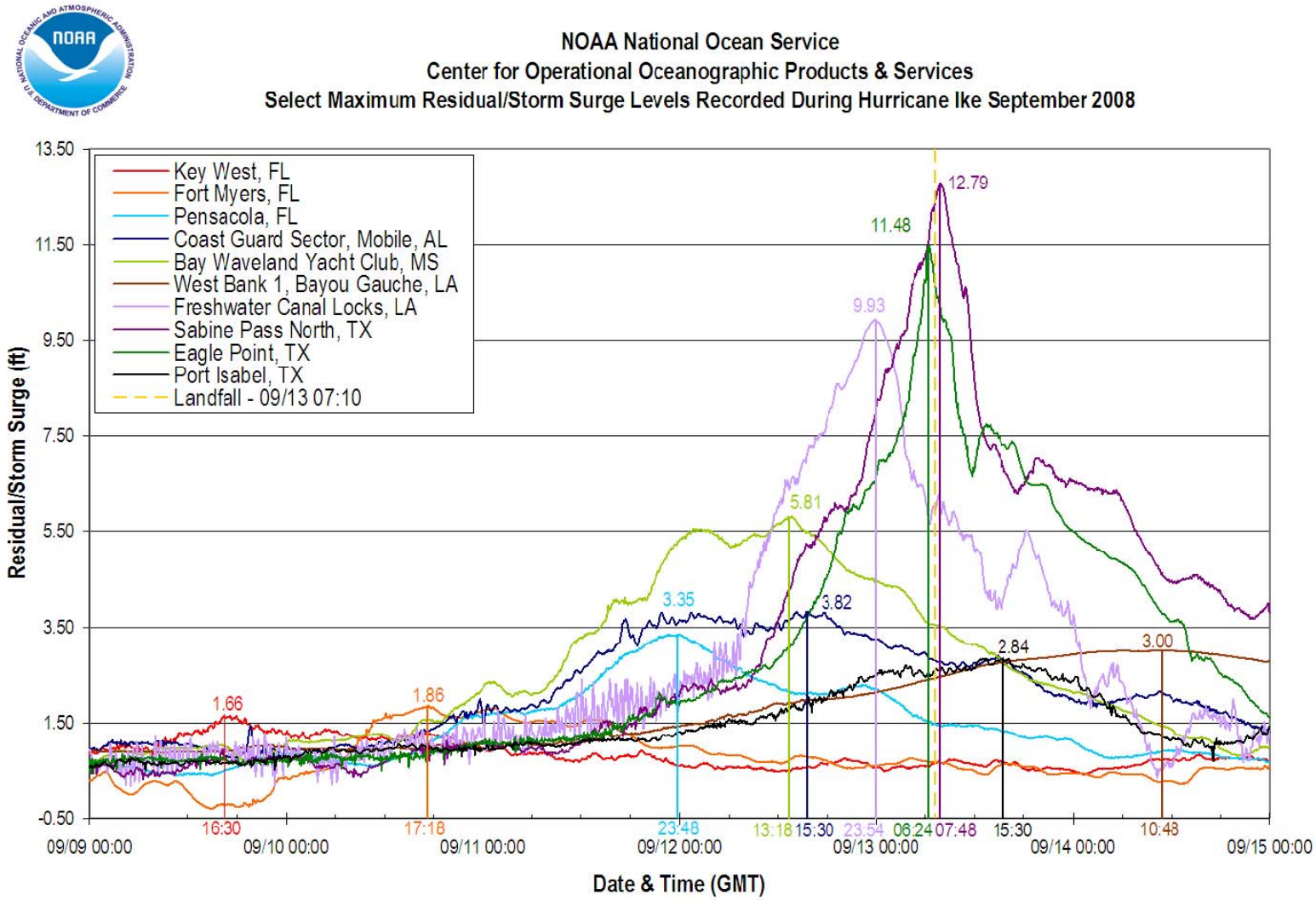


Figure 5. A synopsis of the progression of storm surge associated with Hurricane Ike across the Gulf of Mexico. The time and magnitude of maximum storm surge levels (referenced to Mean Lower Low Water) are shown at geographically representative National Ocean Service observation stations. Figure courtesy of the National Ocean Service.

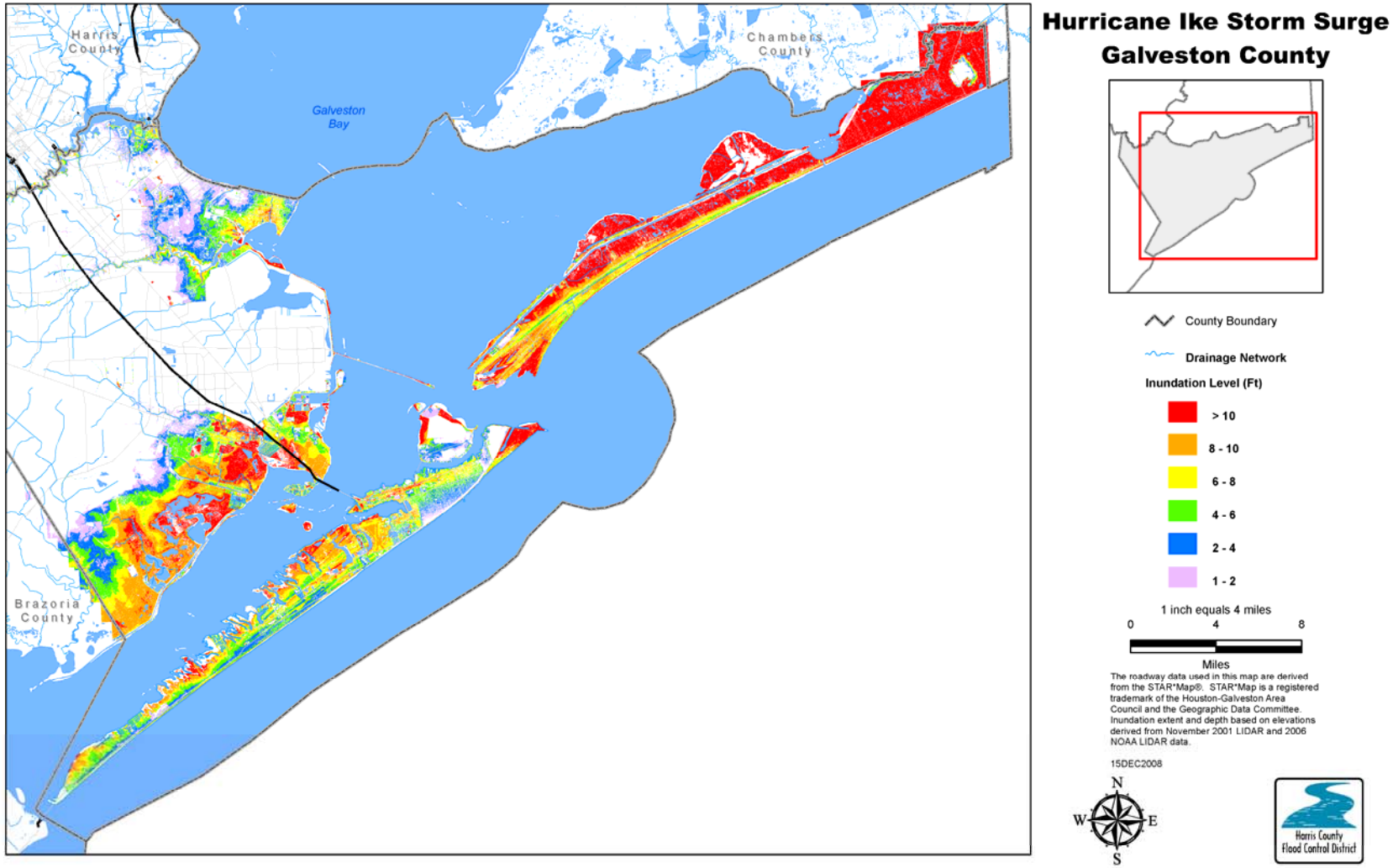


Figure 6. Maximum storm surge inundation levels (water depth) for Galveston County, Texas, including Galveston Island and the Bolivar Peninsula, during Hurricane Ike. Areas shaded in red indicate where the water depths exceeded 10 ft. Image courtesy of the Harris County Flood Control District.

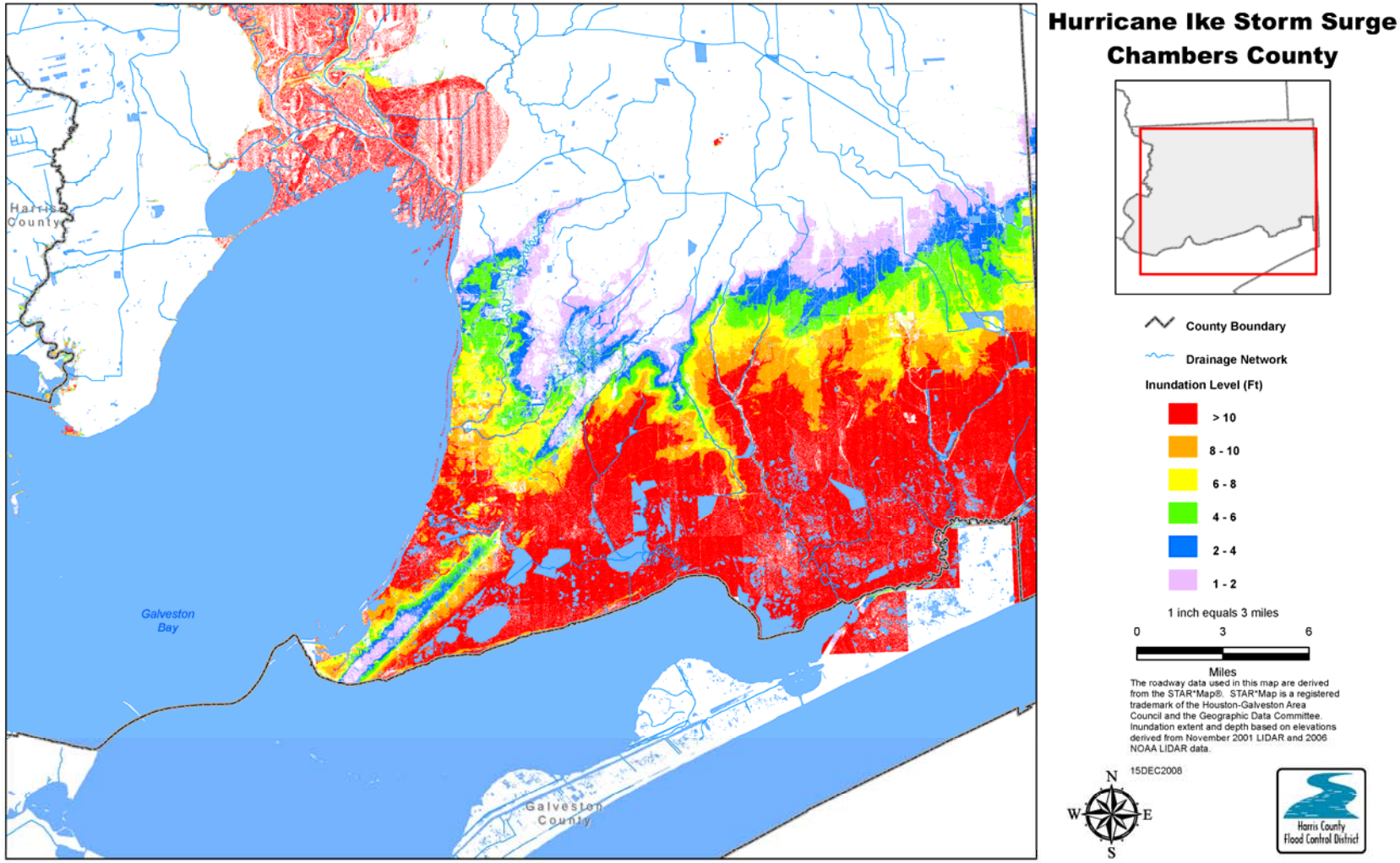


Figure 7. Maximum storm surge inundation levels (water depth) across Chambers County, Texas, during Hurricane Ike. Areas shaded in red indicate where the water depths exceeded 10 ft. Image courtesy of the Harris County Flood Control District.

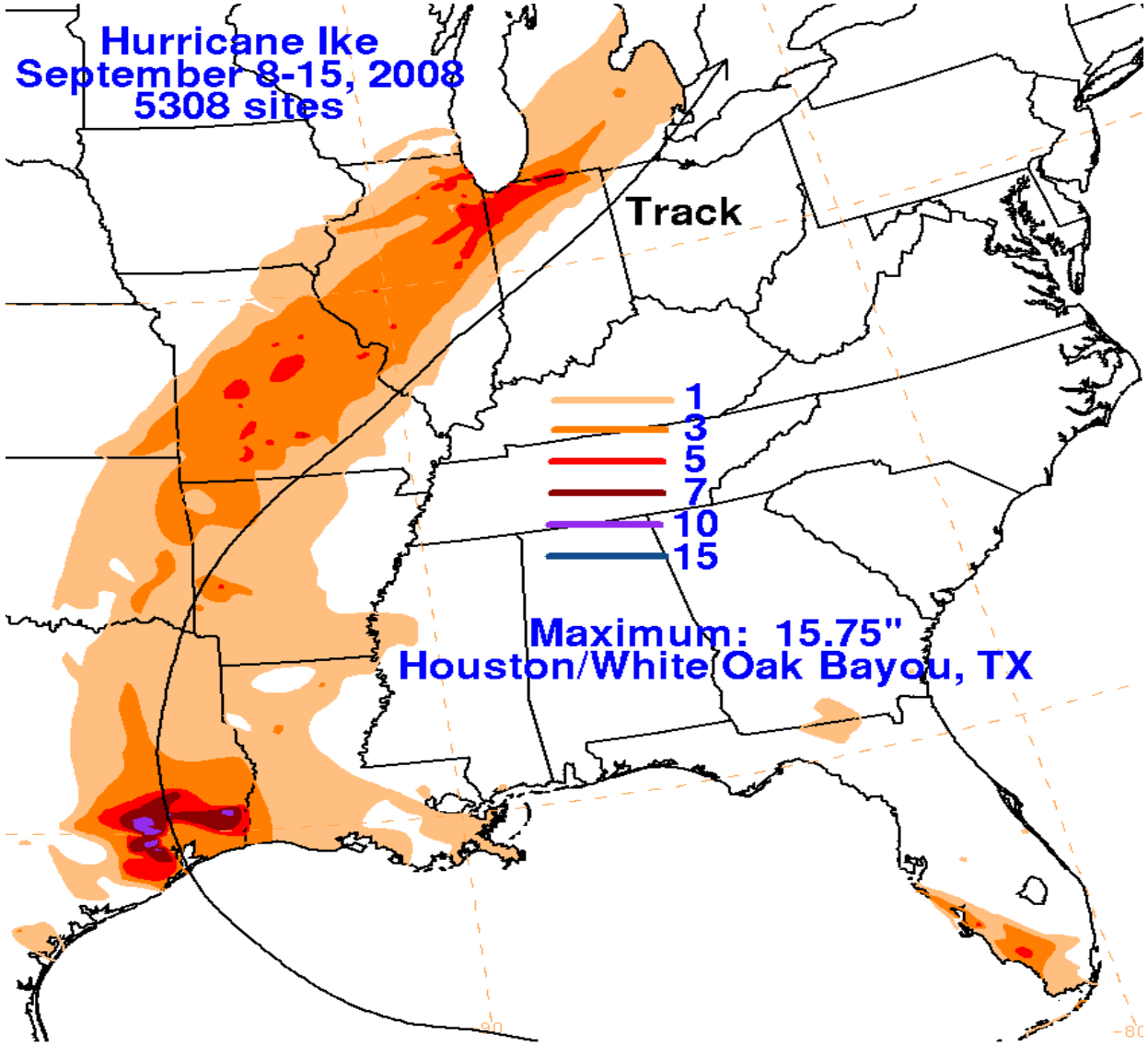


Figure 8. Storm total precipitation associated with Hurricane Ike, 1 – 14 September 2008, and its remnants. Figure courtesy of David Roth at the Hydrometeorological Prediction Center.

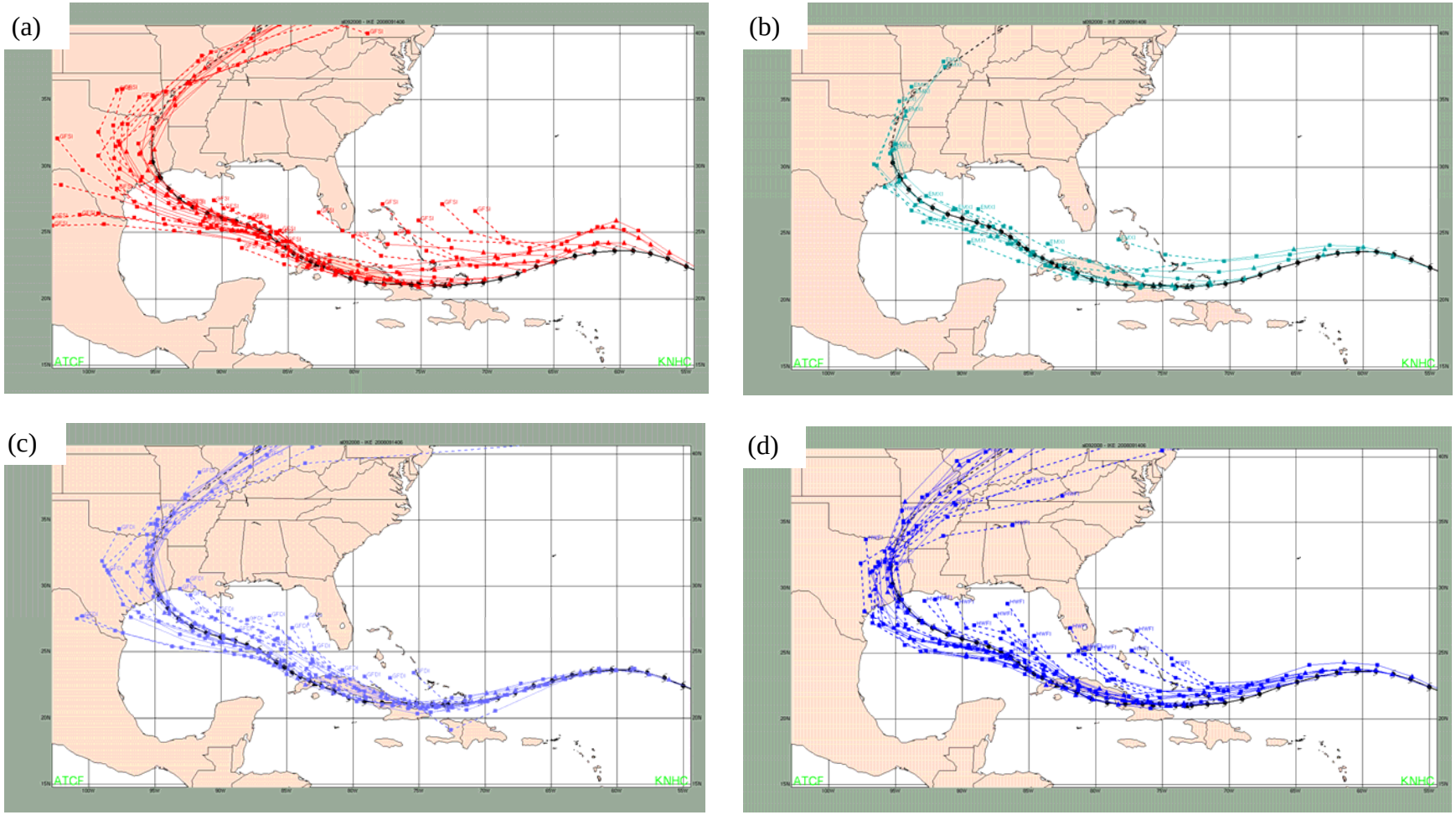
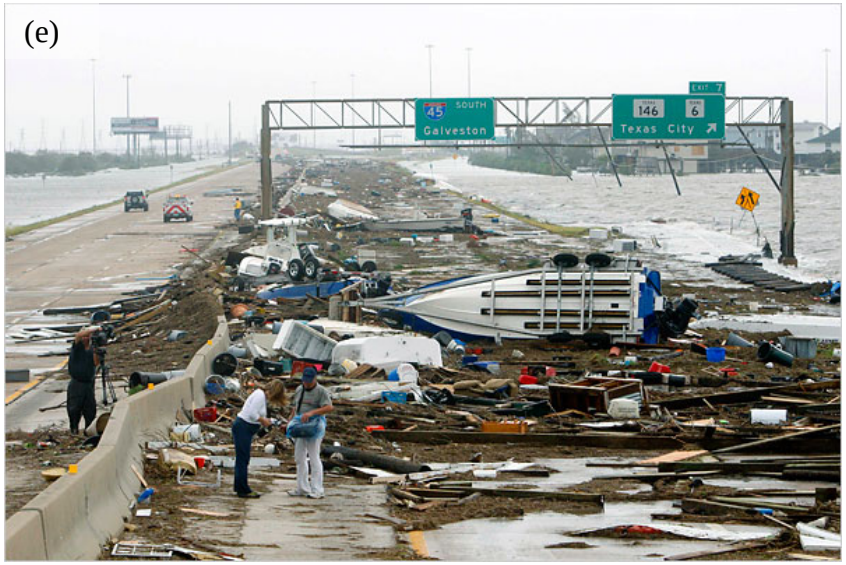


Figure 9. Guidance track forecasts from 0000 UTC 4 September through 0600 UTC 14 September from (a) GFSI (red), (b) EMXI (teal), (c) GFDI (purple), and (d) HWFI (blue) for Hurricane Ike, 1 – 14 September 2008. The best track is given by the thick solid black line with positions given at 6 h intervals.

(a)
(b)
(c)
(d)



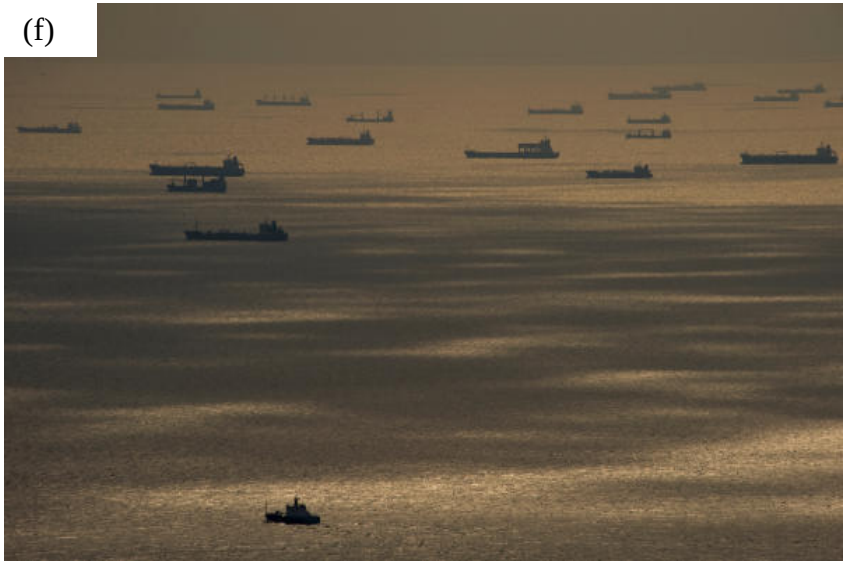


Figure 10. (a) Waves crash over the Galveston Seawall and the memorial for the 1900 Galveston Hurricane before the arrival of Hurricane Ike (courtesy Johnny Hanson, *Houston Chronicle)*. (b) House on fire on Galveston Island as storm surge waters rise in advance of Ike (courtesy Smiley N. Pool, *Houston Chronicle*). (c) Devastation on the Bolivar Peninsula due to storm surge from Ike (courtesy NWS Houston/Galveston and Galveston County Office of Emergency Management). (d) Before and after image of the Bolivar Peninsula depicting the effects of storm surge (courtesy U.S. Geological Survey). (e) Debris, boats, and trailers on the southbound lanes of I-45 heading towards Galveston (courtesy Eric Kayne, *Houston Chronicle*). (f) Ships waiting to enter Galveston Bay after Hurricane Ike (image courtesy Smiley N. Pool, *Houston Chronicle*).