NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

TROPICAL STORM IMELDA

(AL112019)

17–19 September 2019

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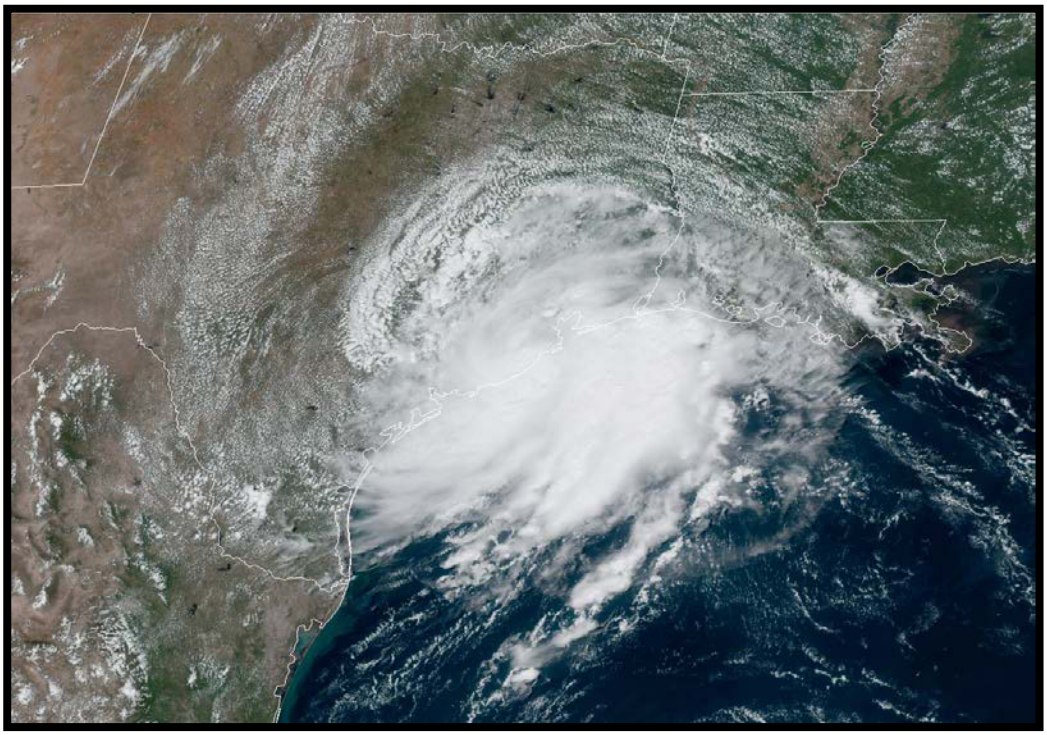
7 February 2020[1]



GOES-16 GEOCOLOR VISIBLE SATELLITE IMAGE OF TROPICAL STORM IMELDA AT 1800 UTC 17 SEPTEMBER 2019. IMAGE COURTESY OF NOAA/NESDIS/STAR.

Imelda was a short-lived tropical storm that moved inland over Texas just after it developed. The storm and its remnants meandered inland for a couple of days after landfall and produced historic rainfall totals and devastating flooding over portions of southeastern Texas.

[1] Original report dated 29 January. This version corrects landfall pressure in Table 1 and the number of and discussion of fatalities in Texas.

Tropical Storm Imelda

17–19 SEPTEMBER 2019

SYNOPTIC HISTORY

The origins of Imelda can be traced back to a mid- to upper-level trough over the eastern United States. A portion of this trough cut off from the mid-latitudes as a mid- to upper-level low that moved southwestward toward the eastern Gulf of Mexico from 10–12 September and associated shower and thunderstorm activity increased from 12–14 September over the eastern Gulf. A weak surface trough developed on 14 September in the vicinity of the upper low and moved west-northwestward toward the central Gulf. The shower and thunderstorm activity covered a large area and remained disorganized through 15 September as the trough moved from the central to the northwestern Gulf. On 16 September, a broad surface area of low pressure formed as the system approached the Texas coast, and later that night convection became more concentrated near the center of the low. Early on 17 September, the low became better defined while convection quickly increased in organization, and a tropical depression formed by 1200 UTC that day while it was located about 40 n mi southwest of Freeport, Texas. Intense convective bursts caused the depression to intensify over the next few hours, and the depression became a tropical storm with 35-kt winds by 1500 UTC while located about 20 n mi south-southwest of Freeport. Imelda continued to strengthen, as indicated by scatterometer wind data, surface observations, and Doppler radar data, reaching its peak intensity of 40 kt at 1745 UTC when it made landfall near Freeport (Fig. 1). The “best track” chart of Imelda’s path is given in Fig. 2, with the wind and pressure histories shown in Figs. 3 and 4, respectively. The best track positions and intensities are listed in Table 1[2].

After moving inland, Imelda quickly weakened to a tropical depression by 0000 UTC 18 September while located just north of Houston. During the next 24 h, Imelda remained a tropical depression and moved slowly northward while producing very heavy rainfall and isolated tornadoes across portions of southeastern Texas and southwestern Louisiana. By 0000 UTC 19 September, the depression degenerated into a trough about 100 n mi north-northeast of Houston. The remnants meandered and continued to produce heavy rainfall over southeastern Texas and southwestern Louisiana during the next day or so and then lifted northward and produced heavy rainfall over southeastern Oklahoma before dissipating.

intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), subjective Dvorak technique estimates from 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 Imelda. The National Weather Service WSR-88D radar network provided data for tracking Imelda across the northwestern Gulf of Mexico and portions of Texas.

Selected surface observations from land stations are given in Table 2.

Winds and Pressure

Imelda's estimated peak intensity of 40 kt is based on a combination of ASCAT data that showed peak winds of 38 kt as well as several land-based surface observations reporting sustained winds speeds ranging from 32–38 kt during that time period. Doppler radar from Houston (KHGX) indicated equivalent surface winds of 38–43 kt between 1745–1800 UTC 17 September, just prior to landfall. However, the higher values in the radar data were transient and not representative of the sustained winds. Therefore, an average of the two values were used. The minimum surface pressure of 1003 mb is estimated from a surface observation that reported 1005.9 mb with 25–30 kt of wind at 1724 UTC at the Freeport Harbor Texas Coastal Ocean Observing Network (TCOON) site (FPST2).

Rainfall and Flooding

A steady influx of deep tropical moisture into Imelda and its remnants, combined with the system's slow looping motion over eastern Texas, produced widespread rainfall amounts greater than 30 inches across several counties, including portions of the Houston metro area and Beaumont (Fig. 6). The highest rainfall total was 44.29 inches recorded 2 miles south-southwest of Fannett, Texas (Fig. 7). Also noteworthy about the Fannett rainfall total is that 31 inches fell in 12 h. This rainfall caused devastating flooding along the I-10 corridor from Winnie eastward to Fannett, Beaumont, Vidor, and Orange, Texas (Fig. 8). During the height of the flooding, numerous vehicles were either stuck or flooded on I-10 between Beaumont and Winnie for 2.5 days. The 44.29-inch peak rainfall total makes Imelda the 7th-wettest tropical cyclone (in terms of highest rainfall total for a tropical cyclone) to impact the United States, the fifth wettest in the contiguous United States, and the fourth wettest in the state of Texas since 1940. These rains came only 2 years after Hurricane Harvey set the record as the wettest tropical cyclone on record in the U.S. and it affected some of the same areas as Imelda.

The remnants of Imelda lifted northward across Oklahoma on 20–21 September, producing as much as 7.6 inches of rainfall over the southeastern portion of the state.

Storm Surge[3]

Minor coastal flooding due to storm surge occurred at some locations along the coast of Texas on the day of Imelda's landfall. However, flooding near the coast worsened in the ensuing days due to the contribution of freshwater runoff from Imelda's heavy rains, and several coastal tide gauges measured peak water levels a few days after landfall. When isolating the data to 17 September, the day of Imelda's landfall, the highest measured storm surges were 2.35 ft and 2.31 ft above normal tide levels at National Ocean Service (NOS) gauges at Eagle Point and Morgans Point, Texas, respectively, on Galveston Bay. The combined effect of the surge and tide produced inundation levels of 1 to 2 ft above ground level primarily along the upper Texas and extreme southwestern Louisiana coasts, including Galveston Bay. A TCOON gauge at San Luis Pass and an NOS gauge at Galveston Pier 21 each recorded maximum water levels of 2.1 ft above Mean Higher High Water (MHHW) through 17 September. Storm tide observations above MHHW from NOS and TCOON gauges (Fig. 5), which provide rough approximations of inundation above normally dry ground near the gauge locations, are marked with an asterisk for those that include the effects of both freshwater runoff from Imelda's heavy rains along with storm surge.

Once freshwater runoff reached coastal areas after 17 September, several sites recorded even higher water levels. A TCOON gauge on the east side of Houston on Buffalo Bayou (Manchester) recorded 4.32 ft above normal tide levels, equating to 3.5 ft MHHW, on 19 September. Similarly, a TCOON gauge at Port Arthur measured a peak water level of 2.4 ft MHHW on 19 September, and the NOS gauge at Eagle Point recorded its peak water level of 2.5 ft MHHW on 21 September.

Tornadoes

There were two confirmed tornadoes associated with Imelda. An EF-1 tornado touched down at 2156 UTC in Harris County, Texas on 18 September, and an EF-0 tornado touched down in Cameron Parish, Louisiana near the town of Hackberry at 1602 UTC 19 September.

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

CASUALTY AND DAMAGE STATISTICS

There were 5 direct deaths[4] caused by Imelda, all of them in southeastern Texas, and all were due to flooding. In Jefferson County, three fatalities were reported. The Texas Department of Public Safety recovered the body of a 52-year-old male from a pickup truck on I-10 approximately 3 n mi west of Beaumont. The Texas Task Force recovered the body of a 47-year-old male from a vehicle found in a canal. A 19-year-old man was trying to lead his horse to safety through floodwaters, but was struck by lightning and drowned.

In Harris County, a 56-year-old male drove his vehicle into a flooded road and drowned. Another male of 52 years of age was found dead in flood waters near a roadway, and it was presumed he drowned in the flood waters.

Floodwaters resulted in numerous high-water rescues throughout southeastern Texas, including several hundred in Harris County. Well over a thousand vehicles were flooded due to high waters on I-10 and throughout the Houston area. In Chambers County, Texas, Riceland Medical Center was evacuated as it took on water, and flood waters entered numerous homes and businesses across the county. Many roadways were impassible due to the flooding, and many vehicles were stranded in the flood waters. Similar conditions occurred in Hardin County, with river and bayou flooding lasting for days after the rains ended, especially in Pine Island Bayou. Preliminary data suggest that the third highest crest since 1967 occurred for the gauging station near Sour Lake.

The damage caused by Imelda was primarily flood related, with Jefferson County receiving the greatest amount of damage and where many high water rescues also occurred. An estimated 5,100 homes were flooded in the county. Many roads were impassible with numerous vehicles left stranded by motorists. In Harris, Liberty, and Montgomery counties, up to 3,100 homes were flooded.

Louisiana as a result of Imelda. On 17 September, the Baton Rouge airport reported a wind gust of 57 kt. These winds were responsible for flipping 4 airplanes and ripping multiple hangar doors.

The total damage total from Imelda is estimated to be near $5 billion according to NOAA National Centers for Environmental Information.

FORECAST AND WARNING CRITIQUE

Genesis

Although Imelda was recognized to have the potential to develop, it was not expected to do so. The disturbance from which the tropical storm developed was introduced into the Tropical Weather Outlook (TWO) at 0600 UTC 14 September (78 h prior to genesis) with a low chance (<40%) of formation during the next 5 days (Table 3). The system was entered into the 2-day probabilities with a low chance of development 72 h before formation occurred. Neither the 5-day nor the 2-day formation chances reached the medium or high categories prior to genesis. Although the global models were indicating that a low could briefly form near the Texas coast, there was uncertainty as to whether the system would organize during the limited time it was expected to remain over the northwest Gulf of Mexico.

Track and Intensity

Imelda was a tropical cyclone for only 36 h, and there were only 3 forecasts made by NHC before the system weakened to a tropical depression over land. Therefore, the number of available forecasts is too small to draw any meaningful conclusions. The three official NHC forecasts that were made had average track forecast errors of 12.7, 24.7, and 52.2 n mi at 12, 24, and 36 h, respectively, which were near or below the 5-yr means. NHC intensity forecasts had errors of 1.7, 3.3, and 0.0 kt, at 12, 24, and 36 h, respectively, which were also below the 5-yr means.

Watches and Warnings

Tropical storm watches and warnings associated with Imelda are shown in Table 4. Due to the unexpected development and intensification of Imelda, the tropical storm warning was issued only 45 min before landfall, and tropical storm conditions were first reported on land in Freeport 18 min after the warning was issued. It should be noted that the heavy rainfall threat was mentioned by the NOAA Weather Prediction Center (WPC), NWS Weather Forecast Office (WFO) products, and in the NHC TWO well in advance of the impacts.

ACKNOWLEDGEMENTS

John P. Cangialosi produced the track map. Data in Table 2 were compiled from Post Tropical Cyclone Reports (PSH) issued by the NWS WFOs in Lake Charles and Houston and the National Ocean Service. The rainfall data in Table 2 and the map in Figure 7 were provided by David Roth from WPC. Damage, flooding, and fatality reports were provided by the Lake Charles and Houston WFOs.

Table 1. Best track for Tropical Storm Imelda, 17–19 September 2019.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
17 / 1200	28.3	95.7	1008	30	tropical depression
17 / 1500	28.6	95.5	1006	35	tropical storm
17/ 1745	28.9	95.4	1003	40	"
17 / 1800	29.0	95.4	1003	40	"
18 / 0000	29.5	95.5	1007	30	tropical depression
18 / 0600	29.9	95.6	1007	30	"
18 / 1200	30.4	95.5	1007	30	"
18 / 1800	30.6	95.0	1007	30	"
19 / 0000	31.1	94.8	1009	25	"
19 / 0600					dissipated
17 / 1745	28.9	95.4	1003	40	maximum winds, minimum pressure, and landfall near Freeport, Texas

Table 2. Selected surface observations for Tropical Storm Imelda, 17–19 September 2019.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Texas									
International Civil Aviation Organization (ICAO) Sites									
Galveston Scholes Field (KGLS) (29.27N 94.87W)	17/2240	1009.8	17/2033	29 (2 min, 10 m)	35				
Houston Hobby Airport (KHOU) (29.65N 95.28W)	18/0053	1007.1	18/0053	26 (2 min, 10 m)	37				
Jack Brooks Regional Airport (KBPT) (29.95N 94.02W)									22.83
Weatherflow Sites									
Surfside Beach (XSRF) (28.93N 95.29W)			17/1720	38[f] (1 min, 8 m)	44				
Galveston Fishing Pier (XGPR) (29.25N 94.85W)			17/1950	34 (1 min, 12 m)	42				
Clear Lake Park (XCLP) (29.56N 95.07W)			17/2023	32 (1 min, 10 m)	38				
Levee (XLEV) (29.42N 94.89W)			17/1958	29 (1 min, 8 m)	36				
Galveston Bay (XGAL) (29.54N 94.91W)			17/2042	28 (5 min, 5 m)	36				
National Ocean Service (NOS) Sites									
Eagle Point (EPTT2) (29.49N 94.91W)	17/2154	1008.7	17/2012	32 (2 min, 6 m)	38	2.35		2.5*	
Rainbow Bridge (RBBT2) (29.98N 93.88W)						2.24*	2.81*	2.2*	
Morgans Point, Barbours Cut (MGPT2) (29.68N 94.99W)	19/1018	1009.1	16/2000		42 (9 m)	2.31	3.31*	2.1*	
Galveston Pier 21 (GTOT2) (29.31N 94.79W)	19/1006	1009.4	16/2000			2.13	3.34	2.1	
Galveston Bay Entrance, North Jetty (GNJT2) (29.36N 94.72W)	19/1000	1008.6	17/1054		37 (12 m)	2.24		2.0	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Texas Point, Sabine Pass (TXPT2) (29.69N 93.84W)	19/1006	1008.9	17/1754	35 (4 m)	42	2.10		1.9*	
Sabine Pass North (SBPT2) (29.73N 93.87W)	19/1006	1011.8	17/1806		36 (4 m)	2.06		1.9*	
Freeport (FCGT2) (28.94N 95.30W)	17/1736	1006.3	17/1718	25 (6 min, 8 m)	37 (8 m)	1.87		1.6	
Bob Hall Pier, Corpus Christi (MQTT2) (27.58N 97.22W)	19/2306	1008.4				1.72	2.76	1.6	
Matagorda Bay Entrance Channel (MBET2) (28.43N 96.33W)	18/0906	1007.8				2.06		1.5	
Rockport (RCPT2) (28.02N 97.05W)	18/2254	1009.3				1.28	2.69	1.4	
Sargent (SGNT2) (28.77N 95.62W)	18/0842	1008.4	20/1224		37 (8 m)	1.95*		2.1*	
Texas Coastal Ocean Observing Network (TCOON) Sites									
Manchester (NCHT2) (29.73N 95.27W)	17/2306	1007.3				4.32*		3.5*	
Port Arthur (PORT2) (29.87N 93.93W)	19/0706	1010.6				2.49*	2.97*	2.4*	
High Island (HIST2) (29.59N 94.39W)	19/0948	1008.2				2.68*		2.3*	
Rollover Pass (RLOT2) (29.52N 94.51W)	19/1000	1008.9				2.45*	2.89*	2.3*	
San Luis Pass (LUIT2) (29.08N 95.13W)						2.16	2.91	2.1	
Sargent (SGNT2) (28.77N 95.62W)	18/0842	1008.4				1.95*		2.1*	
Galveston Railroad Bridge (GRRT2) (29.30N 94.90W)	17/2136	1008.8				2.09	2.91*	1.9*	
Matagorda City (EMAT2) (28.71N 95.91W)	18/0848	1008.1				2.05		1.9	
Port O'Connor (PCNT2) (28.45N 96.40W)	18/0912	1008.9				1.90		1.6	
Port Aransas (RTAT2) (27.84N 97.07W)	18/2254	1009.6				1.87	2.38	1.6	
Aransas Pass (ANPT2) (27.84N 97.04W)	18/2254	1008.5				1.78		1.6	

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)				
Aransas Wildlife Refuge (AWRT2) (28.23N 96.80W)	18/2230	1008.7				1.73		1.6	
Port Lavaca (VCAT2) (28.64N 96.61W)	18/2218	1008.9				1.79		1.5	
Freeport SPIP, Freeport Harbor (FPST2) (28.94N 95.29W)	17/1736	1005.6	17/1718	35 (15 m)	41	1.76		1.5	
USS Lexington, Corpus Christi Bay (TAQT2) (27.81N 97.39W)	19/2124	1008.1				1.70	2.51	1.5	
Packery Channel (PACT2) (27.63N 97.24W)	19/2206	1009.4				1.00	2.22	1.4	
Seadrift (SDRT2) (28.41N 96.71W)	18/2236	1009.3				1.49	2.57	1.3	
Texas Jefferson County Drainage District 6 Sites									
Fannett 2 SSW (5600/JZXT2) (29.90N 94.27W)									44.29
Hamshire 2 WSW (7100/JYRT2) (29.85N 94.35W)									43.28
Fannett 3 S (5620) (29.88N 94.26W)									42.29
Fannett 5 WNW (5400) (29.95N 94.33W)									41.69
Winnie 5 NW (6350) (29.86N 94.45W)									40.78
China 6 S (6200) (29.97N 94.34W)									40.08
Fannett 6 ENE (3300) (29.97N 94.17W)									39.49
Fannett 5 N (3020) (30.01N 94.26W)									38.35
Beaumont 6 S (2900/JZNT2) (30.00N 94.16W)									37.40

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)				
Fannett 5 N (3100/JZOT2) (29.99N 94.24W)									36.30
Devers 1 WNW (2950) (30.03N 94.60W)									36.26
Fannett 6 WSW (6000) (29.96N 94.35W)									36.11
China 4 SSE (6100) (30.00N 94.30W)									35.15
East Fork Oyster Bayou (4150) (29.73N 94.50W)									34.56
Beaumont 5 SSW (2320) (30.02N 94.16W)									34.42
Nome 6 S/ China 7 SSW (5500/JZWT2) (29.95N 94.40W)									34.34
Central Gardens 5 NW (2500/JZJT2) (30.03N 94.08W)									33.62
Hankamer 7 E (6250) (29.86N 95.51W)									32.76
Beaumont 3 S (2300/JZHT2) (30.04N 94.15W)									32.68
Nome 1 NW (1100/JZAT2) (30.04N 94.43W)									32.09
S 8th & Washington Blvd (2400) (30.06N 94.12W)									31.46
Beaumont 4 SSW (2800/JMZT2) (30.04N 94.18W)									31.26
China 2 S (5200/JZTT2) (30.03N 94.33W)									30.51
China 1 NE (5100) (30.06N 94.32W)									30.35
Beaumont 2 SSW (2200/JZGT2) (30.06N 94.16W)									29.17

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)				
Hamshire 5 SSW (7200/JYST2) (29.79N 94.33W)									28.97
Hamshire 5 ESE (6400/JYHT2) (29.85N 94.23W)									28.81
Fannett 7 ESE (5700/JYZT2) (29.87N 94.16W)									27.87
Central Gardens 7 SW (3000/JYIT2) (29.93N 94.11W)									27.32
Pine Island Bayou (1200) (30.09N 94.40W)									27.25
Beaumont 4 WSW (2700/JZLT2) (30.07N 94.20W)									27.08
Beaumont 3 S (2420) (30.05N 94.14W)									26.69
Beaumont 2 WSW (2600/JZJT2) (30.08N 94.18W)									26.58
China 5 ESE (5300/JZUT2) (30.03N 94.26W)									26.54
Hamshire 5 SE (7000/JYQT2) (29.81N 94.26W)									26.50
Beaumont 5 WSW (3500/JYTT2) (30.06N 94.21W)									25.67
Hankamer 4 E (3150) (29.86N 94.56W)									25.67
Beaumont 1 ENE (3600/JYUT2) (30.10N 94.13W)									25.64
Beaumont 1 SE (3700/JYVT2) (30.08N 94.14W)									25.44
Beaumont 1 WNW (2100/JZFT2) (30.09N 94.16W)									23.07
Beaumont 3 NNE (4400/JYWT2) (30.13N 94.12W)									22.68

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Bevil Oaks 4 S (5800/JYCT2) (30.13N 94.12W)									22.40
Sea Rim State Park 6 NNW (6700/JXAT2) (29.77N 94.10W)									21.17
Sea Rim State Park 9 NW (6500/JYYT2) (29.77N 94.17W)									20.08
Hamshire 9 SE Pipkin Ranch (6720) (29.77N 94.20W)									20.04
Bevil Oaks 1 SSE (1300/JYNT2) (30.14N 94.28W)									19.69
Sea Rim State Park 8 NNW (6600/JYZT2) (29.80N 94.10W)									19.41
Beaumont 3 NNW 4200/JYAT2) (30.13N 94.16W)									19.41
Bevil Oaks 2 SE (1400/JZCT2) (30.14N 94.25W)									18.93
Daisetta 3 N Batiste Creek (700) (30.16N 94.64W)									18.85
Port Arthur 10 WSW (5820) (29.84N 94.10W)									18.42
Oak Island 2 NE (2050) (29.68N 94.67W)									18.19
Sea Rim State Park 6 N (6900) (29.77N 94.04W)									18.04
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Roman Forest 1.9 ENE (TX-MNG-63) (30.19N 95.13W)									33.01
Beaumont 3.3 SW (TX-JJ-9) (30.05N 94.18W)									30.44
Cleveland 3.6 S (TX-LR-13) (30.29N 95.08W)									22.40

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)				
Nederland 1.8 W (TX-JJ-15) (29.97N 94.03W)									21.46
Galveston 6.4 NE (TX-GV-18) (29.28N 94.80W)									20.62
Dayton 0.2 E (TX-LR-14) (30.05N 94.89W)									19.88
Galveston 8.3 NE (TX-GV-73) (29.30N 94.78W)									19.19
Dayton 1.1 SE (TX-LR-15) (30.04N 94.88W)									18.11
Galveston 5.6 NE (TX-GV-62) (29.28N 94.82W)									18.01
Harris County Flood Warning System Sites									
East Fork San Jacinto @ FM 2090 (795) (30.21N 95.10W)									31.72
East Fork San Jacinto @ FM 1485 (790) (30.15N 95.13W)									29.64
Peach Creek @ FM 2090 (785) (30.23N 95.17W)									28.08
Caney Creek @ FM 2090 (780) (30.26N 95.30W)									25.20
Huffman 3 N Luce Bayou (1940) (30.07N 95.10W)									22.52
Crosby 6 NE (1740) (29.97N 94.99W)									20.76
Bevil Oaks 4 S (5800/JYCT2) (30.13N 94.12W)									22.40
Huffman Repeater (1930) (30.04N 95.07W)									20.00
Lake Houston Dam Spillway (750) (29.92N 95.14W)									19.00

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Lake Houston @ 1960 (740) (30.02N 95.12W)									18.32
GOES Data Collection Platform Rain Gauge									
Beaumont 2 SSE (JZIT2) (30.06N 94.25W)									31.46
Beaumont (BEAT2) (30.10N 94.10W)									31.00
Roman Forest 3 SE (NCET2) (30.15N 95.12W)									29.72
Sour Lake 3 S (JZBT2) (30.09N 94.40W)									29.72
Splendora (SPDT2) (30.23N 95.17W)									27.04
Sour Lake 5 SE (SOLT2) (30.11N 94.33W)									25.45
Sargent 1 ENE (SECT2) (28.84N 95.66W)									23.06
Caney Creek 8 W Splendora (SDAT2) (30.30N 95.30W)									22.84
Dayton 4 NNW (KNFT2) (30.10N 94.93W)									19.99
NWS Cooperative Observer Program (COOP) Sites									
China 3 ENE (BAGT2) (30.07N 94.29W)									27.63
Other Sites									
Mauriceville 1 W (KTXORANG29) (30.22N 93.89W)									31.68
Peach Creek @ US 59 N (4750) (30.16N 95.21W)									27.56
Porter 2 SW (E9829) (30.07N 95.25W)									21.35

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)				
Mauriceville 5 ESE (KTXORANG55) (30.20N 93.79W)									19.49
Tarkington Prairie 3 NW (K6R3) (30.20N 93.79W)									18.20
Louisiana									
National Ocean Service (NOS) Sites									
Freshwater Canal Locks (FRWL1) (29.55N 92.31W)	19/0936	1012.5				2.38		1.7	
Calcasieu Pass (CAPL1) (29.77N 93.30W)	18/1018	1010.7	17/1342		37 (12 m)	2.16		1.6	
Lake Charles (LCLL1) (30.22N 93.22W)	18/0854	1011.7				1.88		1.6	
Lake Charles Bulk Terminal (BKTL1) (30.19N 93.30W)						2.09		1.5	
Calcasieu Parish Police Jury Rain Gage Network									
L-9 @ Old River Road (4000) (30.35N 93.69W)									12.02
L-13 @ HWY 109 (1900) (30.32N 93.66W)									10.89
W6/L3 @ Berry Road (4400) (30.19N 93.63W)									10.39
Hampton Coulee @ Loree Street (3100) (30.19N 93.57W)									10.21
L-4 @ Green Moore Road (4200) (30.26N 93.66W)									10.10
Bearhead Creek @ HWY 12 (4100) (30.33N 93.63W)									7.77
Houston River @ Edgerly Rd. (4700) (30.31N 93.50W)									7.25
L-10C @ WPA Road (4600) (30.28N 93.37W)									7.09
Coon Gully (4300) (30.27N 93.58W)									6.78

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)				
GOES Data Collection Platform Rain Gauge									
Starks 3 NW (CSOL1) (30.35N 93.69W)									12.02
Starks (CSTL1) (30.32N 93.66W)									10.87
Vinton 3 WSW (CBEL1) (30.19N 93.63W)									10.41
Vinton 1 SE (CHCL1) (30.19N 93.57W)									10.20
Starks 4 S (CGML1) (30.26N 93.66W)									10.09
Starks 2 NE (CBHL1) (30.33N 93.63W)									7.77
Vinton 9 NNE (CEDL1) (30.31N 93.50W)									7.25
Oretta 2 S (LCRL1) (30.50N 93.44W)									7.10
Sulphur 7 WNW (CLPL1) (30.28N 93.47W)									7.09
Starks 5 SE (CBWL1) (30.27N 93.60W)									6.78
Other Sites									
Vinton 2 SSE (12093) (30.15N 93.57W)									9.95
Oklahoma									
NWS Cooperative Observer (COOP) Sites									
Antlers 1 W (ATRO2) (34.25N 95.65W)									7.60
GOES Data Collection Platform Rain Gauge									
Sherwood 4 SW (MHSO2) (34.30N 94.83W)									5.83
Antlers 5 W (ANSO2) (34.23N 95.70W)									4.92
Hanobia 1 S (HNBO2) (34.53N 94.93W)									4.87
Broken Bow 9 NE (BKDO2) (34.14N 94.68W)									4.57
Cloudy 6 SSE (CDSO2) (34.23N 95.25W)									4.09

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)				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Kingston 9.0 SSW (OK-ML-3) (33.89N 96.80W)									4.09

[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 some USGS storm tide pressure sensors, inundation is estimated by subtracting the elevation of the sensor from the recorded storm tide. For other USGS storm tide sensors and USGS high-water marks, inundation is estimated by subtracting the elevation of the land derived from a Digital Elevation Model (DEM) from the recorded and measured storm tide. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.
[f] Incomplete data
[*] Surge value includes freshwater runoff from Imelda's heavy rains

Table 3. 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%)	72	78
Medium (40%-60%)	-	-
High (>60%)	-	-

Table 4. Watch and warning summary for Tropical Storm Imelda, 17–19 September 2019.

Date/Time (UTC)	Action	Location
17 / 1700	Tropical Storm Warning issued	Sargent to Port Bolivar
18 / 0000	Tropical Storm Warning discontinued	All

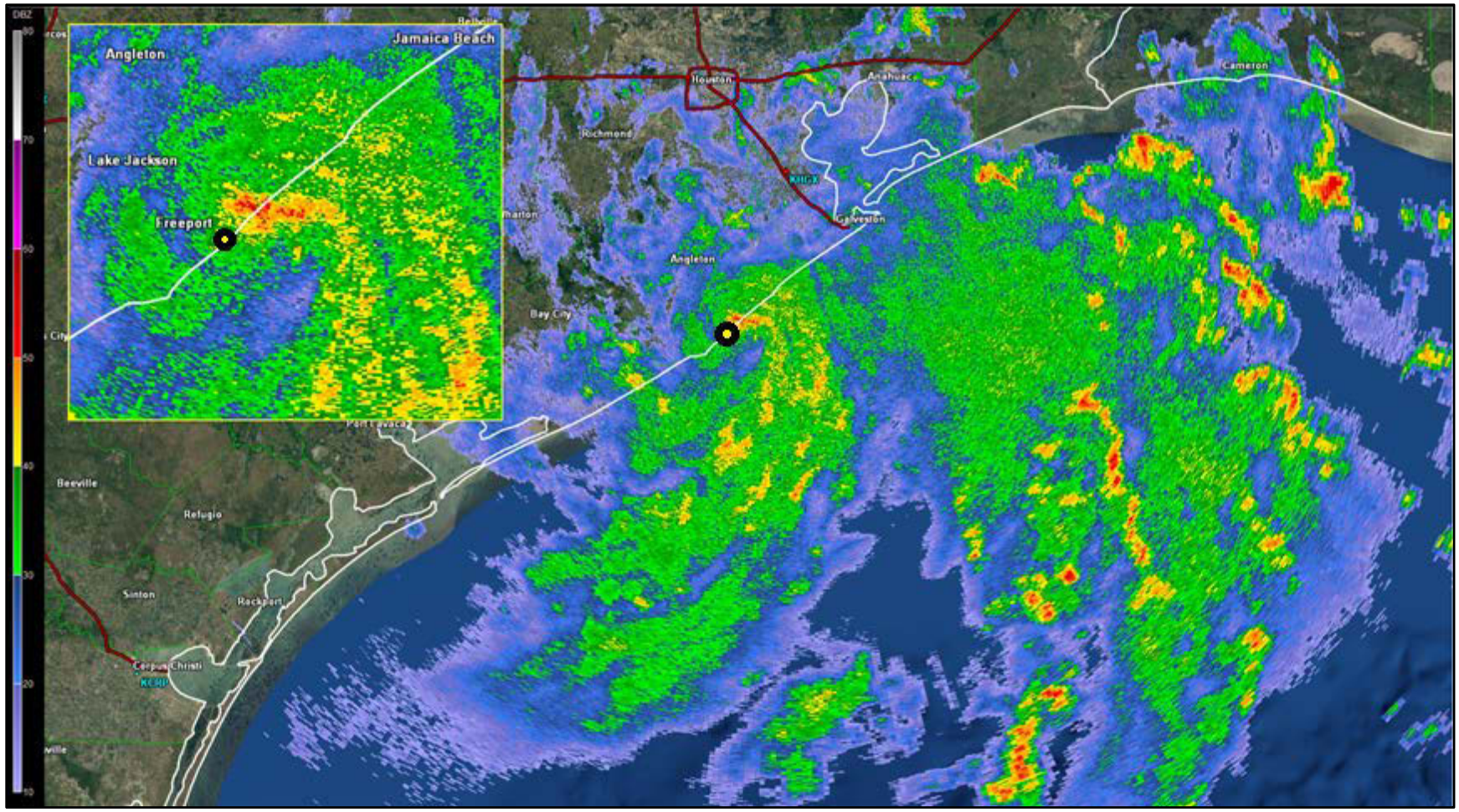


Figure 1. KHGX WSR-88D radar reflectivity (dBZ; 0.5°elev. angle) at 1743 UTC 17 September, very close to the landfall time of Imelda along the Texas coast near Freeport. Center location indicated by yellow dot on inset and larger image. Graphic courtesy of GR2Analyst, Gibson Ridge Software, LLC, Suwanee, Georgia.

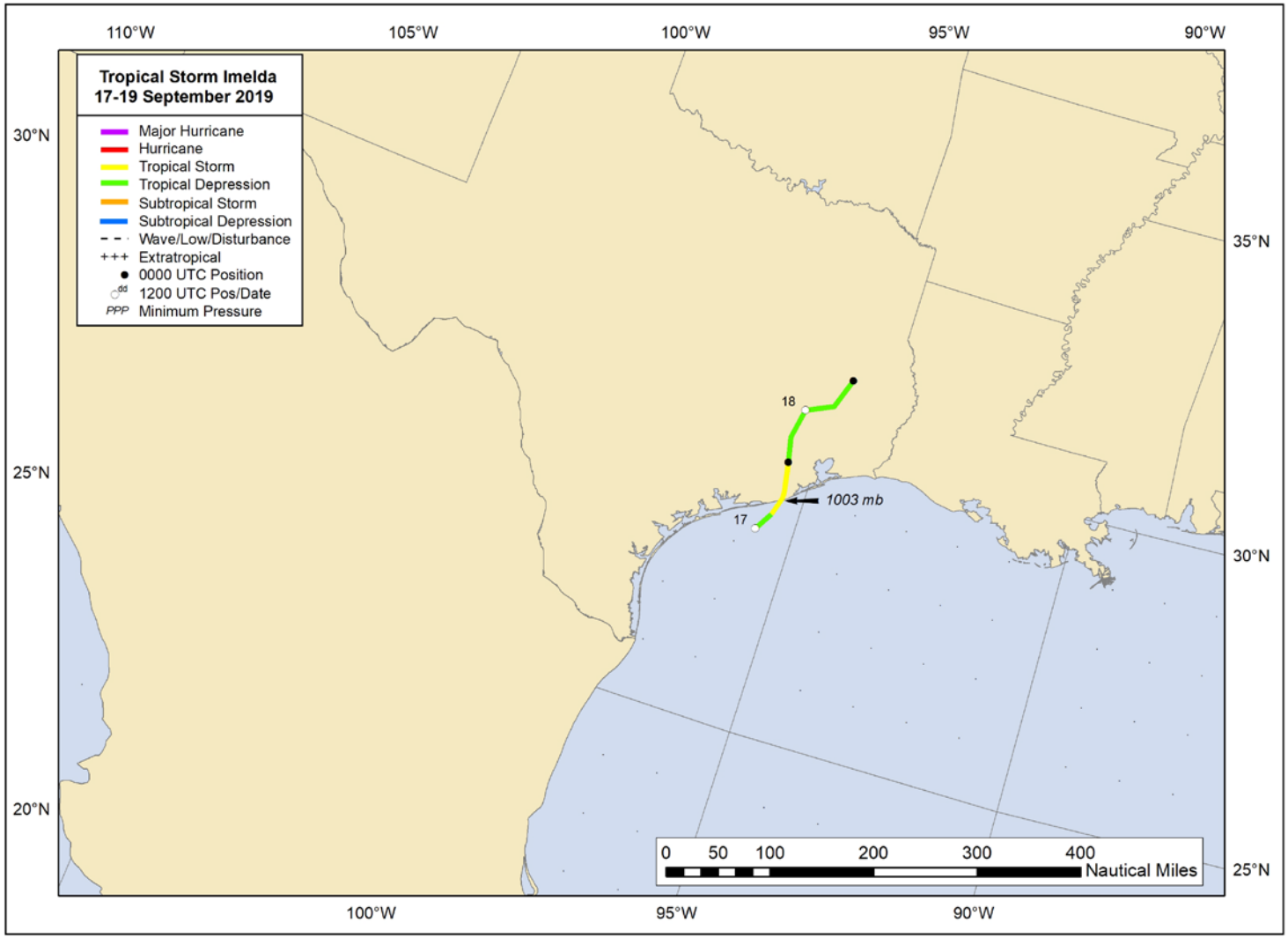


Figure 2. Best track positions for Tropical Storm Imelda, 17–19 September 2019.

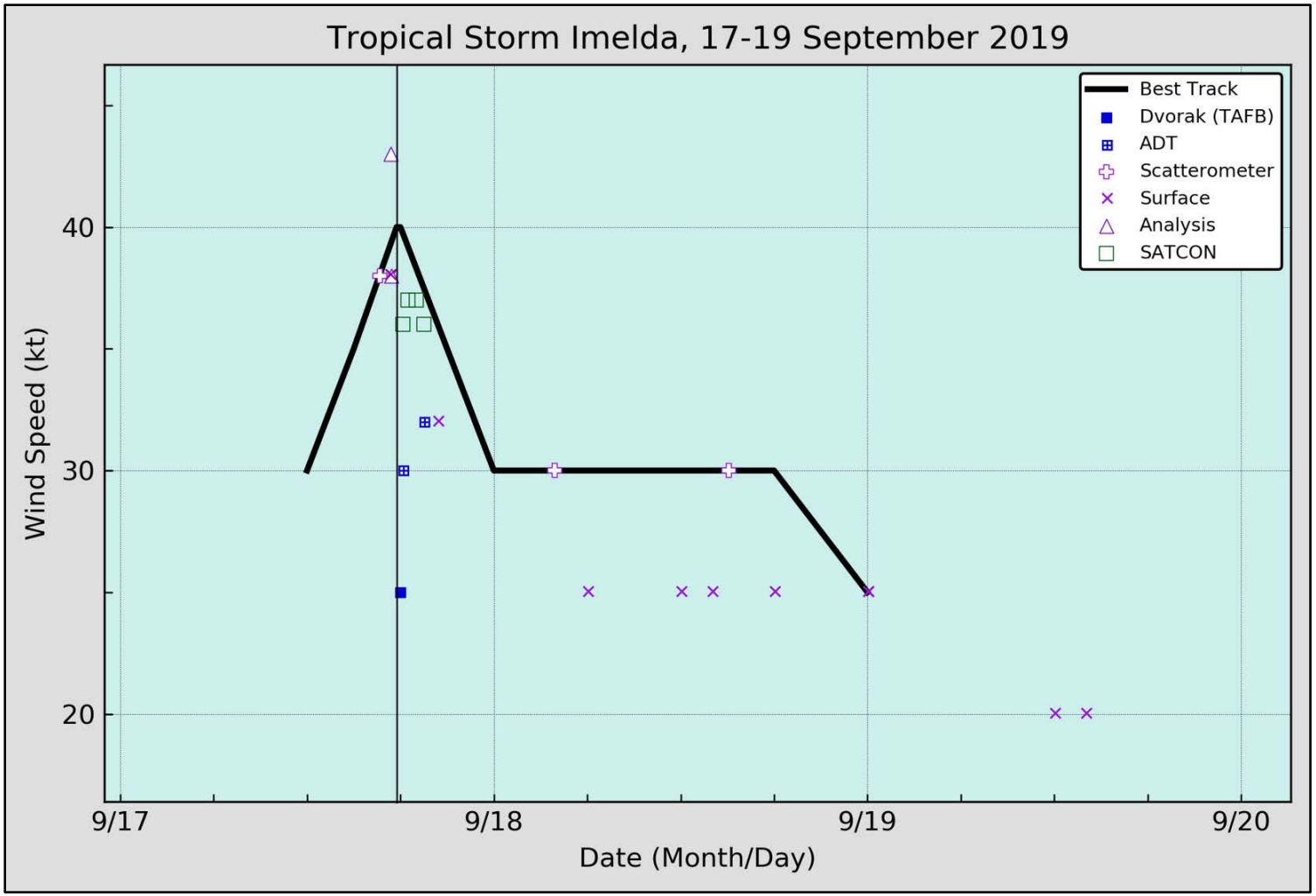


Figure 3. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Imelda, 17–19 September 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC, and the solid vertical line corresponds to landfall.

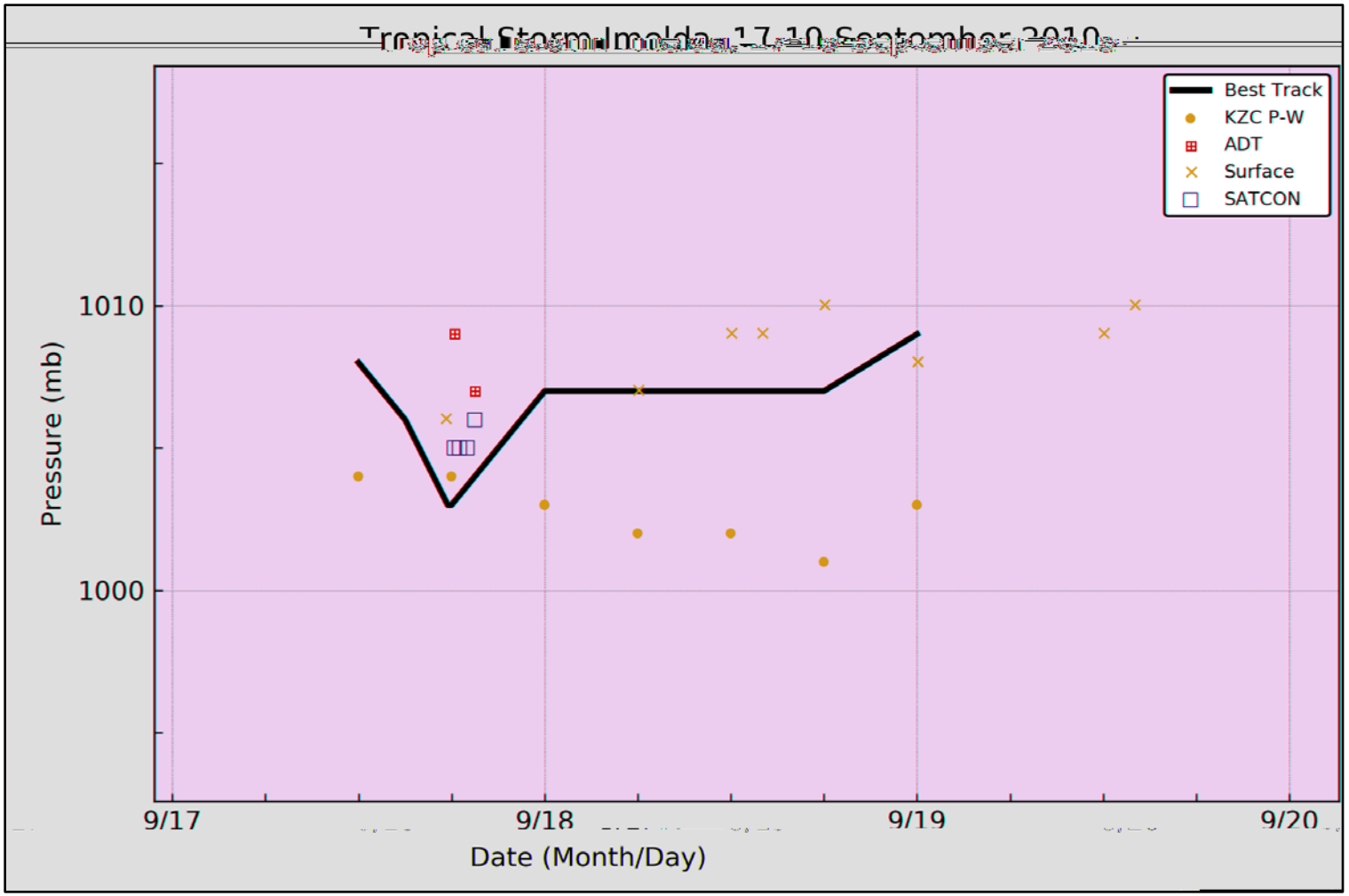


Figure 4. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Imelda, 17–19 September 2019. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and the solid vertical line corresponds to landfall.

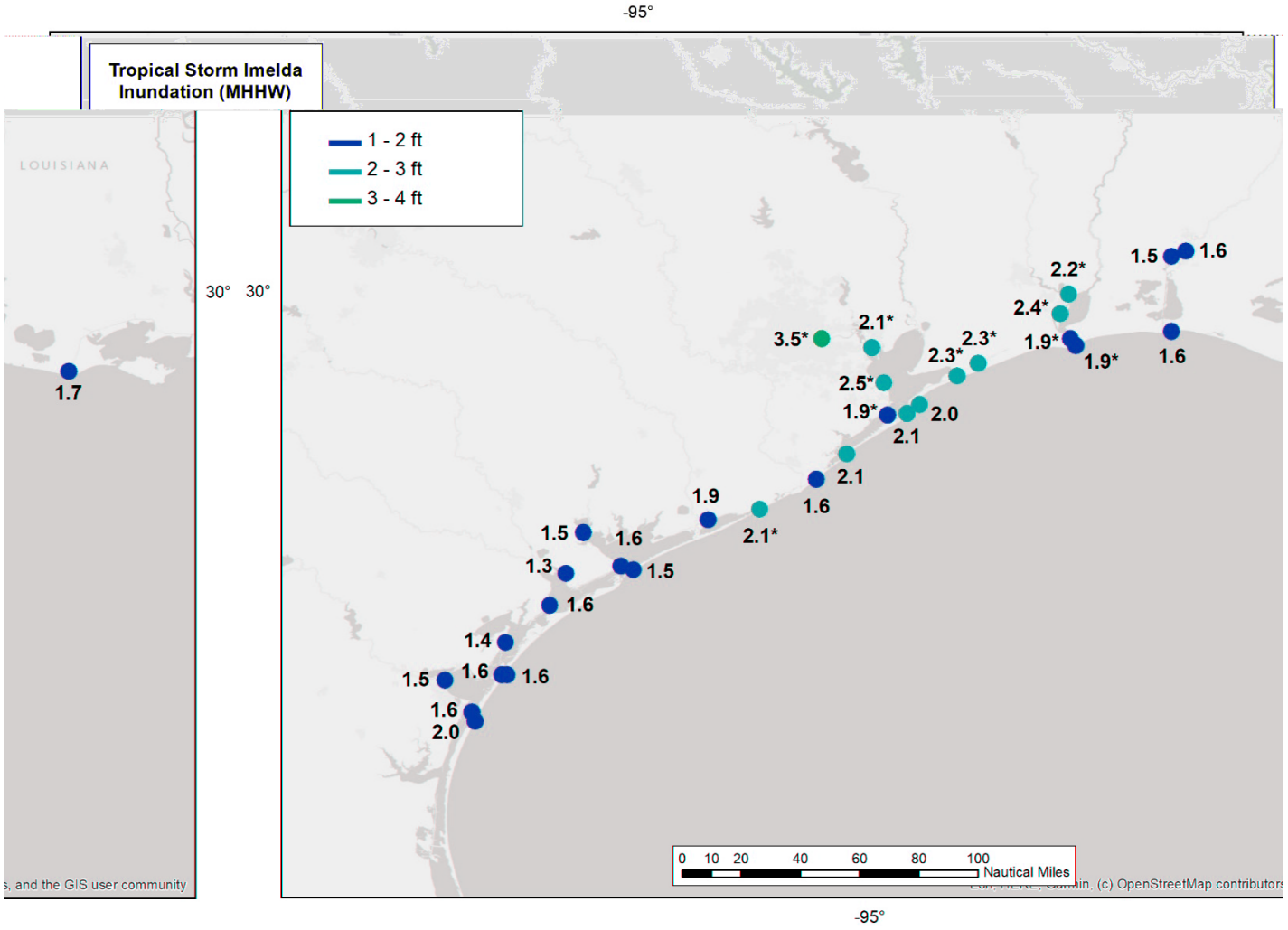


Figure 5. Storm tide measurements (ft) above Mean Higher High Water (MHHW) from NOS and TCOON gauges from Tropical Storm Imelda for the period from 16–21 September 2019. MHHW is used as a proxy for inundation, or storm surge covering normally dry ground. Asterisks indicate peak water levels that were measured after 17 September and include the effects of freshwater runoff from Imelda's heavy rains. Higher peak levels than those depicted on the map occurred at some stations after 21 September.

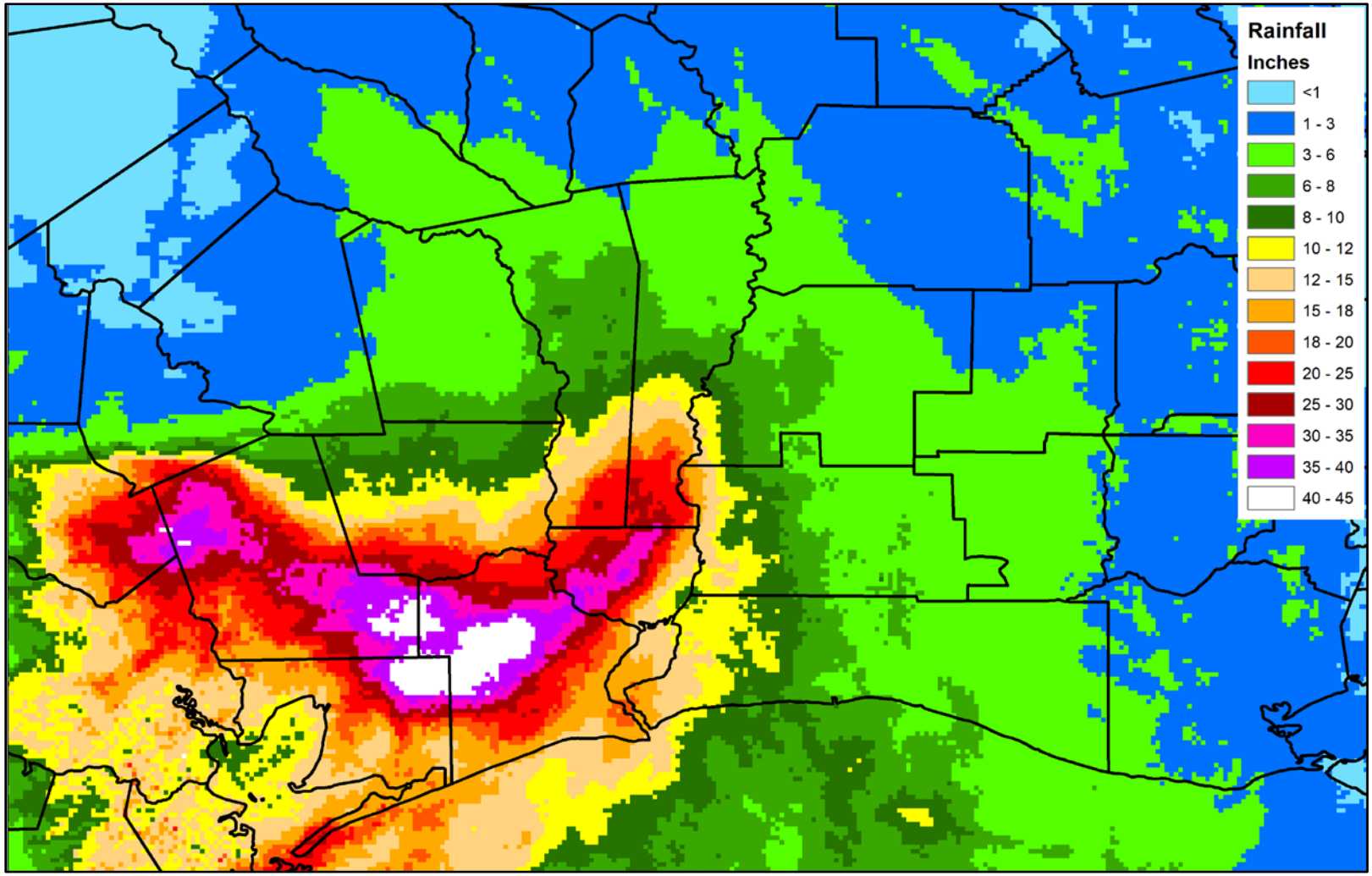


Figure 6. WSR-88D derived rainfall totals (inches) from 1200 UTC September 17 to 1200 UTC September 21, 2019. Image courtesy of NWS Lake Charles, LA.

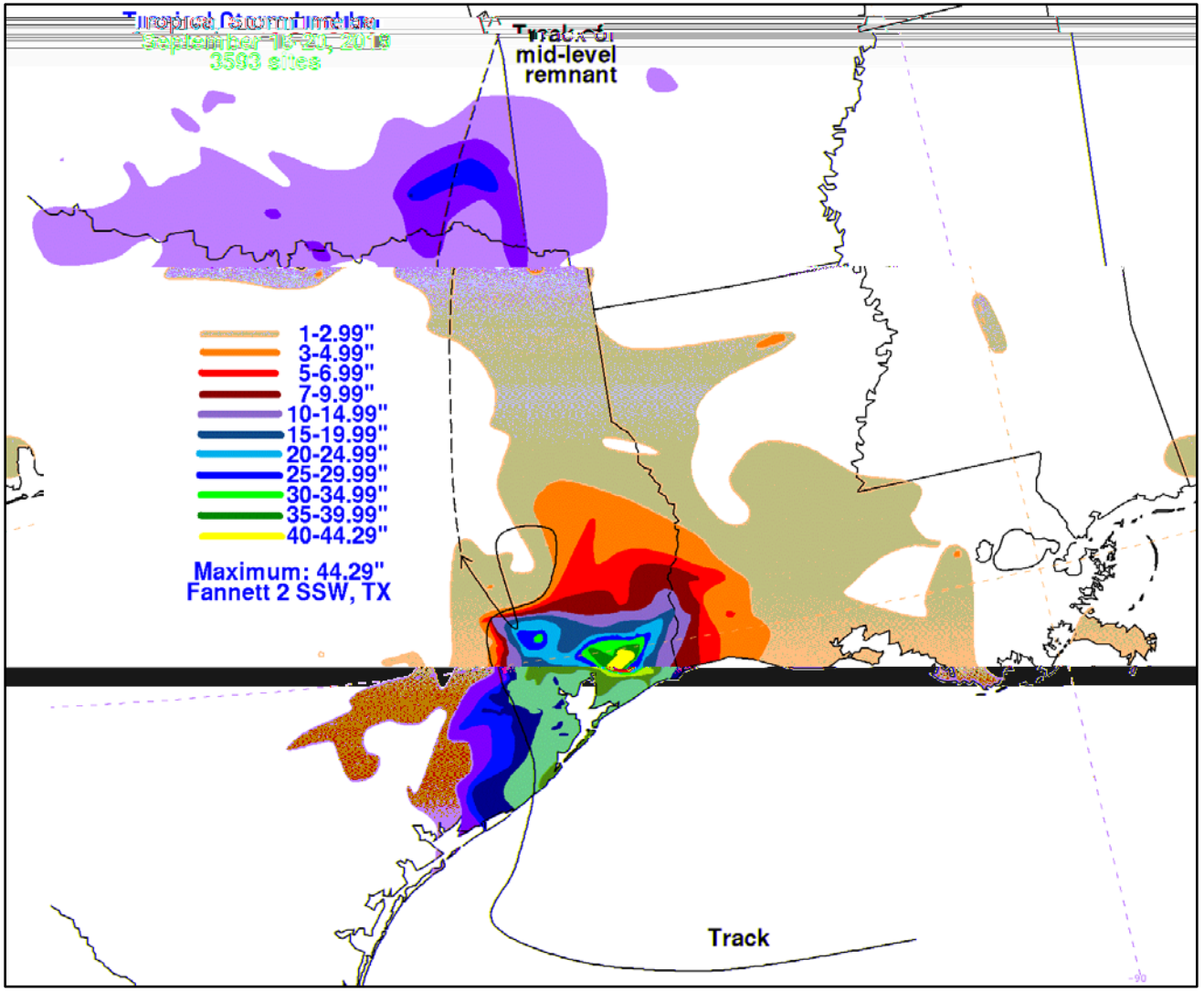


Figure 7. Tropical Storm Imelda total rainfall map (inches) compiled from 3,593 rain gauges from 16–20 September, 2019. Image courtesy of the NOAA Weather Prediction Center.

Figure 8. Flooding that occurred in southeastern Texas as a result of the historic rainfall from Imelda and its remnants. Photos courtesy of the Jefferson County, Texas, Sheriff's Office.