

# OBSERVATIONS OF A TROPICAL STORM IN WEST TEXAS

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## 1. Introduction

Hurricane Claudette made landfall on the Texas coast at Matagorda Island, near Port O'Connor, at 1530 UTC on 15 July 2003 ([Fig. 1](#)). The Category 1 storm resulted in roughly 180 million dollars in damage and two fatalities across the middle Texas coastal region (Beven 2003). Claudette weakened to a tropical storm and moved west-northwest across northern Coahuila, Mexico, before it entered west Texas just north of the Big Bend National Park at 1815 UTC on 16 July.

Meteorological observations suggest Claudette remained a tropical storm as it affected parts of west Texas. The passage of this inland tropical system resulted in strong winds, heavy rainfall, and flash flooding across the Big Bend, Trans Pecos, and the Davis and Guadalupe Mountain regions ([Fig. 2](#)). In addition, severe thunderstorms associated with Claudette's outer rainbands resulted in damaging winds.

The occurrence of a tropical storm, defined as a tropical cyclone with sustained winds between 35 and 65 kt (American Meteorological Society 2000), in west Texas is a rare meteorological event. Observations of a "storm" strength tropical cyclone passing through the region have until now been largely undocumented. Claudette was the first tropical storm observed in west Texas using remote sensing technology implemented during the National Weather Service modernization. This paper will utilize local warning radar (WSR-88D), satellite imagery, and surface observations from automated systems to examine Tropical Storm Claudette's trek across west Texas on 16 July 2003 ([Fig. 3](#)).

## 2. Climatology and Historic Occurrences

West Texas is affected once every three to five years by the remnants of tropical systems that originate in the eastern North Pacific Ocean (Bomar 1983). An investigation of past tropical cyclone paths compiled by Miller et al. (1988) confirms that west Texas is affected more frequently by Pacific cyclones than by Atlantic storms. While the majority of Pacific cyclones follow a general northwest track away from Central America (Elsberry et al. 1987), occasionally these systems curve northeast impacting the west

coast of Mexico. Moisture from these systems will sometimes spread northeast across west Texas to produce increased cloud cover, slightly cooler temperatures, and occasionally moderate to locally heavy rainfall. One of the region's most significant weather events with respect to a Pacific tropical system occurred in September 1972, when moisture associated with the remnants of Tropical Storm Paul resulted in historic floods across west Texas (Bomar 1983).

Examination of historic tropical cyclone data (located on the Tropical Prediction Center/National Hurricane Center (TPC/NHC) Archives website) reveals a strong tendency for systems originating in the Atlantic Basin to curve northward well east of the west Texas area. Prior to Claudette, the only previously documented tropical storm to impact west Texas directly was the Atlantic system "Celia", which moved into the Lower Trans Pecos and Big Bend on 4 August 1970 (Simpson and Pelissier 1971).

### **3. Hurricane Claudette: Storm History**

According to the Tropical Cyclone Report published by the TCP/NHC, Claudette originated from a tropical wave that moved off the west African coast on 1 July 2003 ([Fig. 4](#)). The system was named upon reaching tropical storm strength at 1800 UTC 8 July, just east of the Windward Islands. Claudette briefly obtained hurricane status prior to a glancing landfall on the northeast tip of the Yucatan Peninsula on 11 July. Southwest winds aloft disrupted ventilation of the storm and resulted in fluctuations in convective organization, intensity, and movement as it meandered into the central Gulf of Mexico through 14 July. Claudette once again became a hurricane over the northwest gulf at 0600 UTC on 15 July as it encountered less shear aloft, provided in part by a building deep layer ridge over the Southern Plains ([Fig. 5](#)). The storm's motion then accelerated west-northwest, making landfall on Matagorda Island, Texas, with estimated maximum sustained winds of 80 kt at 1530 UTC on 15 July.

Claudette's winds weakened to tropical storm strength by 0000 UTC 16 July as it continued to move west-northwest under the influence of the southern U.S. ridge. This movement took Claudette to the Rio Grande (U.S./Mexico border) near Eagle Pass, Texas, by 1000 UTC on 16 July.

Claudette's surface circulation was easily seen as it passed between Del Rio and Eagle Pass, with northeast winds and west winds respectively noted on the 1100 UTC surface plot at those locations ([Fig. 6](#)). In addition, upper air soundings taken at six hour intervals as the system passed the Del Rio vicinity depicted thermodynamic and wind profiles characteristic of tropical cyclones, including a dramatic increase in wind speed with height through the first few hundred meters above the surface and a second wind maximum near the 700 hPa level ([Fig. 7a-c](#)). This wind structure was similar to that depicted in a data analysis of Global Positioning System dropsonde wind measurements within tropical cyclones by Powell et al. (2003).

Eight hours later, satellite and regional radar imagery depicted Claudette as a well-organized inland tropical cyclone as it approached west Texas.

#### **4. Observations of Tropical Storm Claudette in West Texas**

Claudette's center of circulation (located using visible satellite imagery, regional composite radar reflectivity, and surface observations) entered eastern Brewster County roughly 82 km southwest of Dryden at approximately 1815 UTC on 16 July ([Fig. 8](#)). Visible satellite imagery depicted a near symmetrical shaped storm that included a dense cloud shield with a diameter of roughly 240 km. Several spiral convective bands also were evident, and extended in excess of 200 km from the storm's center ([Fig. 9](#)).

With a lack of observing sites in the Big Bend and northern Mexico, surface winds with westerly components were not observed south of Claudette's track upon entering west Texas. Therefore, the ability to pinpoint the exact location of Claudette's central surface low was limited. The existence of a surface circulation, however, is easily inferred by the response of the surface flow observed at the Terrell County Airport as the center of the storm passed to the south, and is further inferred by broad cyclonic surface flow depicted across all of west Texas by the surface observing network as the system moved across the region.

Only a few rain gauges were in the path of Claudette as it transited rural west Texas. Although a few residents did report rainfall totals (rainfall reports discussed in section 5a.), precipitation associated with the storm was perhaps best sampled by the Midland WSR-88D (KMAF) radar. The radar's beam, however, overshot much of the precipitation that occurred over northern Mexico and the southern Big Bend. This resulted in a broad semi-circular shaped reflectivity depiction of the rain extending approximately 70 km from the storm's center ([Fig. 10](#)).

The central precipitation area generally appeared uniform with reflectivity values between 25 and 35 dBZ, and was likely comprised of weak convective elements. Virtually no cloud-to-ground (CG) lightning strikes were detected within the central region of the storm by the National Lightning Detection Network. CG lightning activity was more prevalent with outer rainband convection. Similar lightning distributions have been noted with past tropical cyclones (Samsury and Orville 1994; Molinari et al. 1994; Samsury et al. 1995). The intensity and areal coverage of the rainband convection increased through the day as insolation and instability also increased.

Strong to severe surface winds accompanied Tropical Storm Claudette into west Texas. At 1758 UTC an Automated Surface Observation System (ASOS) at the Terrell County Airport (K6R6), located 10 km west of Dryden, measured a fastest two minute east wind of 38 kt. A peak gust of 50 kt also was recorded ([Fig. 11](#)). At the time of these measurements, Claudette's westward moving circulation was located approximately 60 km south-southwest of the Terrell County Airport, and more than 570 km inland from the gulf coast.

At an elevation of 701 m (all elevations relative to mean sea level unless otherwise noted), the Terrell County Airport is located in an area of relatively flat terrain that is void of topographical features that enhance local wind measurements. Claudette's central precipitation shield was moving over the area at the time, and there is no

evidence to suggest strong convection enhanced the observed winds. These ASOS wind measurements combined with the previously discussed satellite and radar imagery observations of the storm's structure suggest that Claudette remained a tropical storm as it moved into west Texas.

Satellite and radar imagery continued to depict evidence of a well-organized tropical system as Claudette tracked further into west Texas. Although the spiraling cloud shield gradually became less symmetrical throughout the day, the center of circulation remained easily identifiable in surface observations, visible satellite, and radar imagery through 2300 UTC.

Observed surface winds were less than 30 kt in the Davis Mountains; however, strong gusts were measured at the McDonald Observatory, 15 km northwest of Fort Davis. These gusts began around 1800 UTC, just as the center of Claudette moved into west Texas. At 1820 UTC the McDonald Observatory recorded a peak gust of 46 kt atop Mount Locke (2,072 m).

Wind measurements from neighboring Mount Fowlkes (2,024 m) were less likely to be obstructed and more representative given the ambient easterly flow. Wind speed plots from Mount Fowlkes indicate a gust of 43 kt at 1930 UTC ([Fig. 12](#)). Both the 1820 UTC gust on Mount Locke and the 1930 UTC gust on Mount Fowlkes occurred well in advance of Claudette's closest approach to the Davis Mountains. These early wind gusts correlate to convective cells embedded within one of Claudette's spiral rainbands observed to pass over the observatory in KMAF reflectivity data ([Fig. 13](#)).

The Mount Fowlkes plot also depicts a maximum wind gust of 46 kt at 2200 UTC. This measurement occurred as Claudette passed approximately 56 km south of the Davis Mountains and the McDonald Observatory around 2230 UTC.

Claudette weakened with time as it propagated across west Texas. Between 2230 and 2300 UTC the storm's center passed less than 30 km southwest of Marfa. Peak sustained winds of 30 kt were recorded with gusts to 36 kt at the Marfa ASOS (KMRF) site ([Fig. 14](#)). These measured wind speeds suggest that Claudette was in the process of weakening, or had already weakened, below tropical storm strength as it moved south of Marfa.

By 0000 UTC on 17 July the middle and upper level circulation seen in satellite imagery was quickly becoming displaced from the low level circulation that was inferred in surface observations. The Tropical Cyclone Report from the TPC/NHC indicates Claudette weakened to a depression at 0000 UTC. By 0100 UTC the upper circulation seen in infrared (IR) satellite imagery was rapidly moving west-northwest, and was located 97 km west of Marfa. At that time, only hints of a low level circulation could be inferred from the region's sparse surface observations southwest of Marfa ([Fig. 15](#)).

The middle and upper level circulation remained visible in IR satellite imagery through the nighttime hours as it moved across northern Chihuahua, Mexico. Although a surface

circulation was not easily identified, breezy northeast to east winds persisted across west Texas in the wake of the departing tropical cyclone.

While Claudette was quickly losing organization over northern Mexico and moving further away from west Texas, significant winds were occurring in the Guadalupe Mountains National Park. Winds exceeding tropical storm criteria were observed by the Guadalupe Pass ASOS (KGDP) at 0600 UTC, which reported east winds sustained at 38 kt with gusts to 45 kt.

Guadalupe Pass is a west-to-east oriented highway pass between the Guadalupe Mountains to the north and the Delaware Mountains to the south, and is located at an elevation of 1,654 m. Channeling of east-west oriented wind flow frequently results in terrain enhanced strong to severe winds through the pass. Given the location and apparent weakening of Claudette at the time of the wind measurements as suggested by other methods of meteorological remote sensing, and the known effects of flow channeling at the pass, the 0600 UTC Guadalupe Pass observation is not considered representative evidence of tropical storm conditions.

## **5. Sociological Impacts**

Two aspects of Tropical Storm Claudette's passage across west Texas presented a threat to life and property. Fortunately, no injuries or loss of life occurred across the region, and only one report of damage was received. Claudette's largest sociological impact on the area was the occurrence of widespread rainfall that provided a minor and short-lived reprieve from the ongoing long term drought conditions. Despite the fact that Claudette's soaking rains were generally welcomed by most of the region's residents, the tropical storm resulted in dangerous flash floods and damaging thunderstorm winds at a few locations.

### ***a. Flash Flooding:***

Although the relatively fast movement (18 kt average) of Tropical Storm Claudette across west Texas limited rainfall amounts and precluded a widespread devastating flood event, heavy rainfall associated with the system resulted in localized flash flooding. Storm total rainfall accumulations between 3.8 and 5.1 cm (1.50 and 2.00 in) were reported by several National Weather Service cooperative observers ([Fig. 16](#)).

Flash flooding was first reported at 2100 UTC in the Big Bend National Park. Locally heavy rainfall caused high water to flow across Highway 385 approximately 62 km south of Marathon in Brewster County. The highway remained closed through 2230 UTC without incident.

As Claudette weakened and re-entered northern Mexico shortly after 0000 UTC on 17 July, strong convection regenerated in the vicinity of the Serranias del Burro Mountains in northern Coahuila. This convection developed in an outer convective band on the east side of the storm's circulation and trained north across Terrell County. As a result, several measured rainfall totals exceeded 3.8 cm (1.50 in). KMAF Storm Total Precipitation estimates by the morning of 17 July 2003 depicted up to 7.6 to 12.7 cm

(3.0 to 5.0 in) of rainfall over rural parts of the county ([Fig. 17](#)). Given the tropical nature of the environment, it is possible these values were underestimated since the non-tropical convective Z-R relationship ( $Z=300R^{1.4}$ ) was utilized throughout the event. These radar estimates were not verified with rain gauge measurements since the rain fell over unpopulated areas. Localized flash flooding resulted from the heavy rainfall and Farm to Market Roads 2400 and 2886 were inundated by flowing water for several hours. Local officials closed these highways from 0140 to 0345 UTC.

***b. Severe Thunderstorm Winds:***

As convection within Claudette's outer spiral band increased in coverage and intensity during the afternoon hours, a few individual thunderstorms became organized and relatively long-lived. One of these storms was observed to produce severe winds that damaged a mobile home and downed a utility pole near the community of Mentone (Loving County) at 2130 UTC.

The most organized storms occurred in an east-to-west oriented segment of the outer rainband which was located north and west of Claudette's central circulation ([Fig. 18](#)). rainbands in this area of a tropical cyclone, the right-front quadrant, have long been recognized to possess favorable vertical shear and buoyancy capable of supporting severe thunderstorms including mini-supercells (Romine and Wilhelmson 2002, McCaul 1991; Novlan and Gray 1974; Hill et al. 1966). Radar interpretation of two cells that appeared to be the strongest and most organized of the event suggested that characteristics of mini-supercells were present and were generally consistent with observations of similar supercell storms associated with tropical cyclones. Distances between the KMAF radar site and the first of these storms, which occurred at a range of over 150 km, prevented opportunities for a detailed radar-based discussion. Much of the second storm's life cycle occurred at a lesser distance from the radar site, between 65 and 160 km. This allowed for a slightly more comprehensive radar investigation, and its characteristics will briefly be discussed.

The storm of interest developed near Monahans in northeast Ward County around 2200 UTC, and moved west-northwest to near the Guadalupe Mountains National Park before dissipating around 2350 UTC. KMAF base reflectivity indicated intermittent elevated 65 dBZ cores up to 6,095 m (20,000 ft) above ground level (AGL). These cores were displaced downwind, or west, of the lower level reflectivity cores by approximately 3 km and provided evidence of reflectivity overhang. Echo tops briefly reached 13.6 km (45,000 ft) AGL during two periods of peak intensity, but averaged 10.5 to 12.0 km (35,000 to 40,000 ft) AGL. These storm top heights are slightly lower than those typically associated with severe storms in west Texas. The thunderstorm's spatial diameter was atypically small, and averaged only 10 km ([Fig. 19](#)).

High resolution (8-bit) Storm Relative Mean radial velocity data depicted uncorrelated shear associated with the storm, but no conclusive evidence of a user-defined mesocyclone ([Fig. 20](#)). Studies by Spratt et al. (1997) and Edwards et al. (2000) suggest that mini-supercell mesocyclones embedded in tropical cyclone rainbands, including those that are tornadic, are often as small as 1km in diameter. Therefore, definitive

conclusions about the storm's supercellular nature should not be based on the lack of a radar observed mesocyclone. Such feature would be too small for the WSR-88D to adequately sample given the range of the storm from the radar site.

## **6. Conclusion**

Early on 16 July 2003, satellite and regional warning radar imagery suggested the inland Tropical Storm Claudette remained unusually organized as it propagated west-northwest across the Mexican state of Coahuila. These remote sensing observations were supported by sustained 38 kt winds measured by an ASOS near Dryden, Texas, as the center of the system crossed the Rio Grande into west Texas around midday. Claudette's track across west Texas resulted in strong to severe winds, flash flooding, and damaging thunderstorm wind gusts.

The occurrence of a tropical storm in west Texas is a rare meteorological event. Claudette was the first such occurrence in over thirty years. Observations of such an event, therefore, had not previously been documented in the region using modern meteorological remote sensing.

It is this paper's intent to provide a brief description of the remote sensing observations of Tropical Storm Claudette and the effects of the storm's passage through west Texas on 16 July 2002. The authors suggest possible avenues for future local research on similar topics that include inland tropical cyclone forecasting and the contributions of these systems to west Texas climatology. In addition, training is needed to enhance forecaster recognition of known critical fire weather patterns and the heightened wildfire potential in advance of approaching inland tropical cyclones (Schroeder 1969). The 107th United States Congress recognized the need for such investigations, and authorized the National Weather Service to conduct research, development, and training aimed at improving inland tropical cyclone forecasting with the passage of Bill H.R. 2486 in July 2001. Although Tropical Storm Claudette did not have a large adverse impact on the region's residents or economy, history has proven that even less organized tropical systems have had devastating effects across west Texas.

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