

Preliminary Report
Tropical Storm Arlene
18 - 21 June 1993

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9 December 1993

a. Synoptic History

A siege of unsettled weather over the western Caribbean Sea and Central America preceded Arlene's formation. As early as 9 June, an area of clouds and scattered deep convection was noted on satellite pictures near the east coasts of Nicaragua and Honduras. The activity spread slowly northwestward and increased a little in areal coverage over the following week. During that period, upper-level winds over the northwestern Caribbean Sea and the Gulf of Mexico were generally from the west or northwest, creating a vertical wind shear that was not favorable for the development of a tropical cyclone.

On the 16th, however, a mid- to upper-level low began to develop over the Bay of Campeche. Downstream, the flow aloft became more anticyclonic over the Yucatan peninsula and the northwest Caribbean Sea. In addition, on that date, a tropical wave neared the Yucatan peninsula from the east-southeast. The net effect of these changes was for the convective activity to expand west-northwestward into an area where the upper-level circulation was somewhat more conducive to the development of a tropical depression. Analysis of surface data suggests that, by late on the 16th, a 1008 mb low formed over the Yucatan peninsula.

A U.S. Air Force Reserve's reconnaissance plane found only a broad area of low pressure in that area at midday on the 17th. However, satellite pictures a few hours later showed convective bands developing just offshore over the south-central Gulf of Mexico, and it is estimated that at 0000 UTC on the 18th the system became Tropical Depression Two (Fig. 1 and Table 1). The depression was centered between the low aloft to the southwest, and a deep-layer-mean high to the northeast. The associated steering flow moved the depression toward the northwest at about five knots.

The center of the depression remained near the eastern edge of the low aloft, in an area of moderate southwesterly vertical wind shear which apparently precluded strengthening of the depression. The low-level center stayed diffuse, with satellite images occasionally showing separate weak low-level cloud swirls in that area. Indeed, the reconnaissance mission late on the 18th measured 1006 mb as the lowest pressure within a broad area for which they could not make a center "fix". By that time, satellite pictures suggest that the upper-level shear over the diffuse center had been further increased by a southwesterly outflow jet cutting across the southwestern Gulf of Mexico from eastern North Pacific Tropical Storm Beatriz.

In the meantime, on the 18th, convection became more

concentrated in a band located about 150 to 200 n mi to the southeast through northeast of the depression center. Over the next 24 hours, the band cyclonically wrapped further around the center, so that by early on the 19th, a comma-shaped band extended from well northwest through north through southeast of the center. It is within that northwestern extension of the convective band that satellite pictures and reconnaissance data indicate a new and dominant (1000 mb) low-level center of circulation formed near 1200 UTC on the 19th (see Fig. 1 and Table 1). It is this second center (located about 100 n mi northwest of the original center) that is designated in the "best track" as Tropical Storm Arlene at 1200 UTC.

The new center initially moved northwestward at about 5 kt, but then nearly stalled when an eastward-moving short-wave trough passed by to the north. The forward motion then became westward at a couple of knots. Arlene made landfall over Padre Island, about 40 n mi south of Corpus Christi, near 0900 UTC on the 20th and weakened to depression strength shortly thereafter. The system remained a tropical depression through 0600 UTC on the 21st. A low- to mid-level remnant circulation could be detected for another day or two over the lower Rio Grande River valley of southern Texas and northeastern Mexico.

b. Meteorological Statistics

The best track intensities were obtained from the data presented in Figs. 2 and 3. Those figures show the curves of Arlene's central pressure and maximum sustained one-minute wind speed, respectively, versus time, and indicate the transition that occurred from the original to the second circulation center.

Although maximum sustained wind speeds near Arlene's center are estimated to have been about 35 kt for the 18 hours ending with landfall, somewhat stronger winds were in the convective band located well to the east of the circulation center. Sustained wind speeds of 40 to 45 kt were reported between 1100 and 2000 UTC by ship C6JP2 (name unknown) and several platforms over the north-central Gulf of Mexico (see Table 2). Similar wind speeds in that vicinity had been encountered by the reconnaissance aircraft at a flight level of 1500 ft. The distant wind maximum and the association of the tropical cyclone with the nearby low aloft indicate that Arlene's structure had some subtropical cyclone characteristics.

Reconnaissance aircraft observed a central pressure of 1000 mb on seven consecutive penetrations of Arlene. This is the estimated minimum pressure of the storm. The pressure at landfall is estimated at 1001 mb.

Arlene generated storm tides of locally up to about four feet along the Texas coast. The storm tide breached sections of Padre Island and caused local flooding on the mainland.

Heavy rain fell for several days over Central America from the weather system that eventually became Arlene. Heavy rains also

occurred over Mexico (Table 2). Arlene brought large accumulations of rain and local floods to the area extending inland about 150 n mi from the Texas coast. Locally heavy rain, from a combination of Arlene and a frontal system, also occurred in northeast Texas, Louisiana, and Arkansas. The town of Henderson, TX reported the largest total, 14.82 in.

No reports of tornadoes associated with Arlene have been received by the National Hurricane Center (NHC).

c. Casualty and Damage Statistics

The prolonged rains over Central America prior to Arlene becoming a tropical cyclone reportedly caused a landslide in El Salvador that killed 20 people. In Mexico, floods from Arlene killed five people (four in the state of Yucatan and one in the state of Campeche.) There was one flood-related fatality reported in Henderson, Texas. Damage in Campeche was reported at \$33 million. Flooding from rainfall was also reported in Texas, Louisiana, and Arkansas. The Texas Division of Emergency Management estimated \$22 million damage to homes, businesses, and infrastructure in that state. Crop losses were not quantified.

The storm tide (Table 2) removed about 6 to 12 inches of sand from some beaches along the lower Texas coast. Extensive tidal flooding was reported on the lower and middle Texas coast as well as along beach access roads. Beach erosion was also reported in southwestern Louisiana.

The threat of flooding prompted the evacuation of about 15 people from summer homes along Magnolia Beach and Indianola, Texas.

d. Forecast and Warning Critique

Arlene was a tropical storm for less than a day. This period is too short to provide meaningful quantitative statistics on forecast accuracy.

Arlene was still a tropical depression when its center moved close enough to the coastline that the issuance of a tropical storm watch was considered. However, because the cyclone was then quite poorly-organized and significant strengthening was not forecast, the NHC, in coordination with the appropriate NWS offices, opted to delay issuing a tropical storm watch. These considerations were outlined in the NHC Tropical Cyclone Discussions (TCDs). When the new and slightly stronger center formed, a tropical storm warning was issued about 21 hours prior to landfall (Tables 3 and 4). There were no observations of sustained tropical storm force winds received from the warned area.

Despite the unusual discontinuous nature of the cyclone's track, the official forecasts fairly accurately indicated a landfall near the mouth of the Rio Grande River, and that the depression would strengthen to become a tropical storm. This was probably a combination of the second center forming along the

forecast track of the first, and the large-scale flow steering that center toward the west-northwest to northwest. The possibility that this new center might form was first noted in the NHC TCD disseminated a few hours prior to the conclusion of that transformation.

The threat of flooding was first indicated at 0900 UTC 18 June, in NHC's second Public Advisory: "This weather system has a history of producing very heavy rain resulting in localized flash floods. Additional rainfall totals of 5 to 10 inches are possible near and along the path of the depression."

Acknowledgments

Some of the data in this report were provided by the National Data Buoy Center (NDBC) and NWS WSO reports from Brownsville, Corpus Christi, Victoria, Houston, Shreveport, and Lake Charles.

Table 1. Preliminary best track, Tropical Storm Arlene, 18-21 June 1993.

Date/Time (UTC)	Position		Pressure (mb)	Wind speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
18/0000	20.5	91.9	1006	25	Tropical Depression
0600	20.8	92.3	1005	25	" "
1200	21.1	92.8	1005	25	" "
1800	21.7	93.1	1005	30	" "
19/0000	22.6	93.4	1006	30	" "
0600	23.8	94.1	1006	30	" "
1200	25.9	95.9	1000	35	Tropical Storm (new center)
1800	26.0	96.3	1000	35	" "
20/0000	26.3	96.7	1000	35	" "
0600	27.0	97.2	1001	35	" "
1200	27.2	97.8	1002	30	Tropical Depression
1800	27.2	97.9	1003	30	" "
21/0000	27.1	98.1	1004	30	" "
0600	27.1	98.3	1006	25	" "
1200					Remnant Low

19/1200-20/0000 see above 1000 35 Minimum Pressure

Landfall:

Padre Island (about 40 n mi south of Corpus Christi)

20/0900 27.1 97.4 1001 35 Tropical Storm

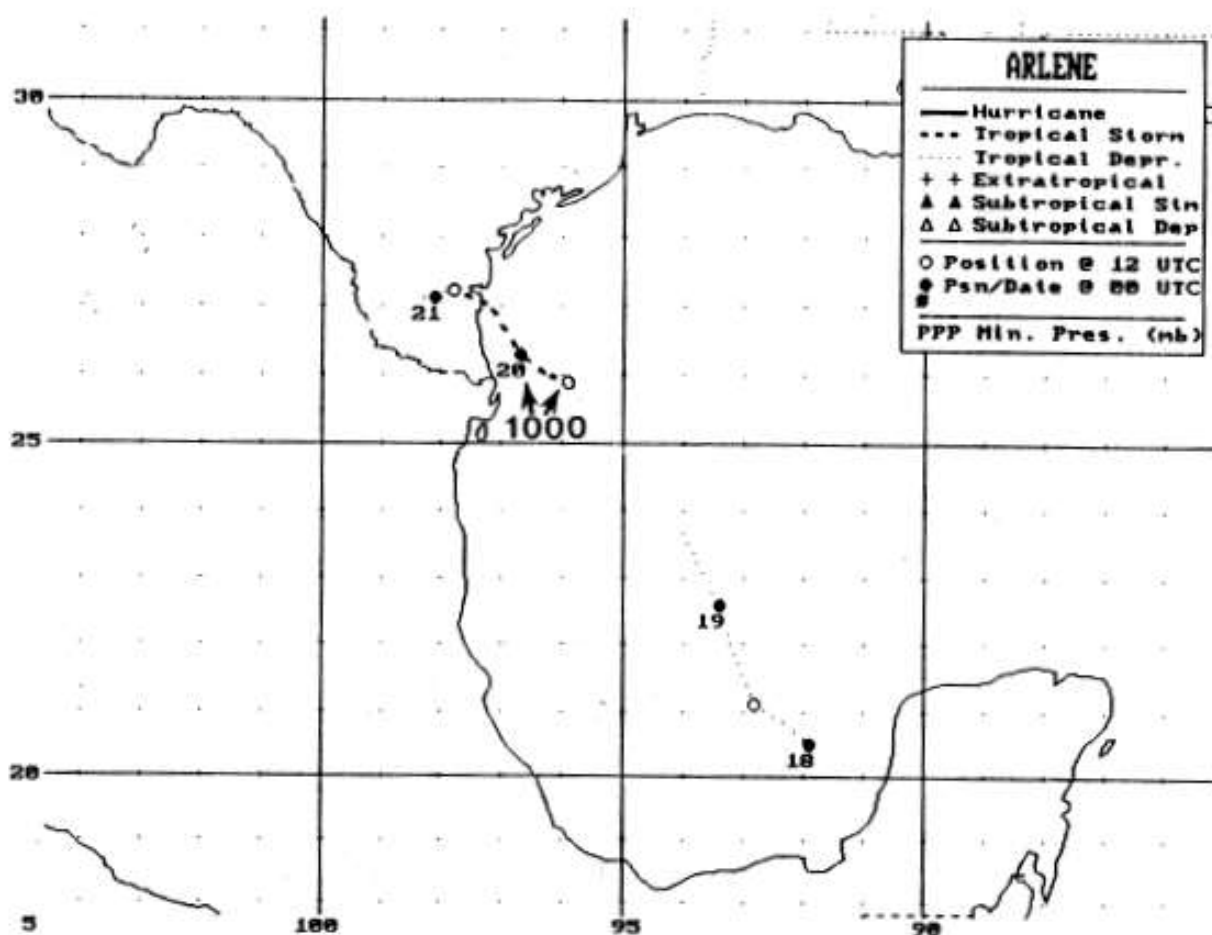


Figure 1. Best track positions for Tropical Storm Arlene. Dual track explained in text.

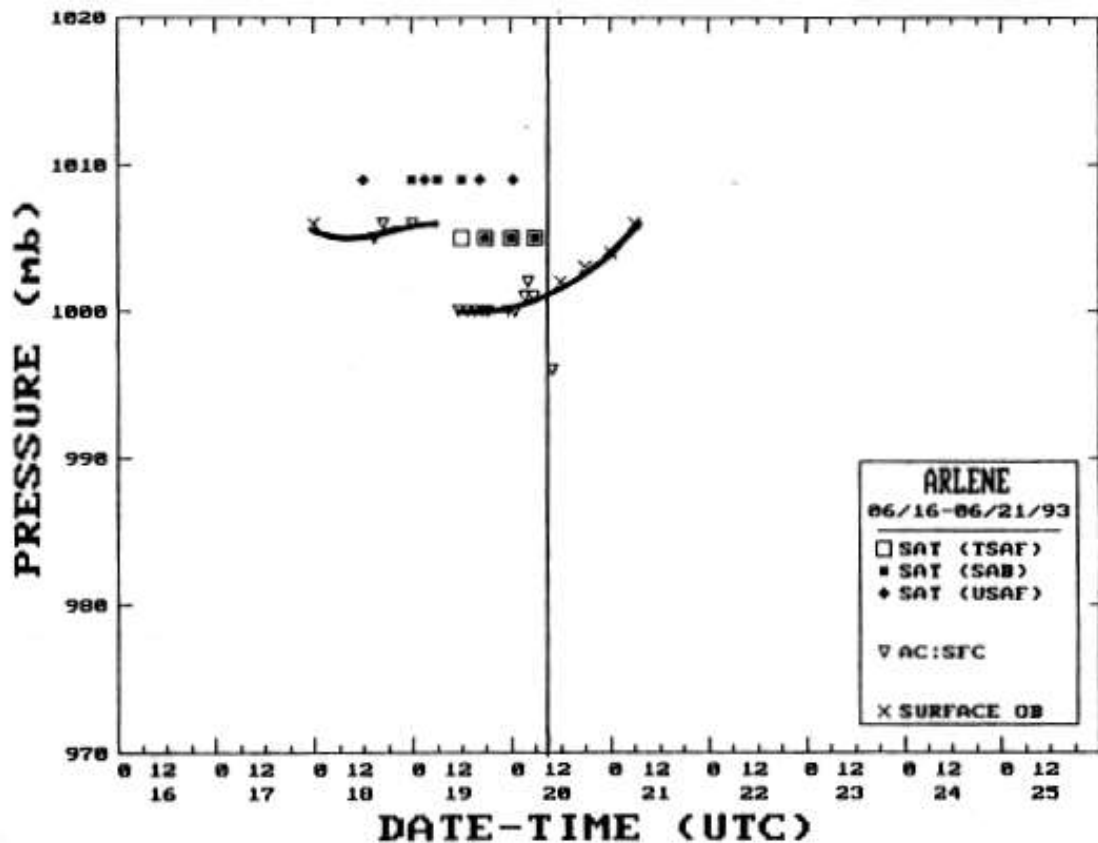


Figure 2. Best track central pressure curve for Tropical Storm Arlene, June 1993. X indicates surface analysis. Vertical line denotes landfall. Dual curves explained in text.

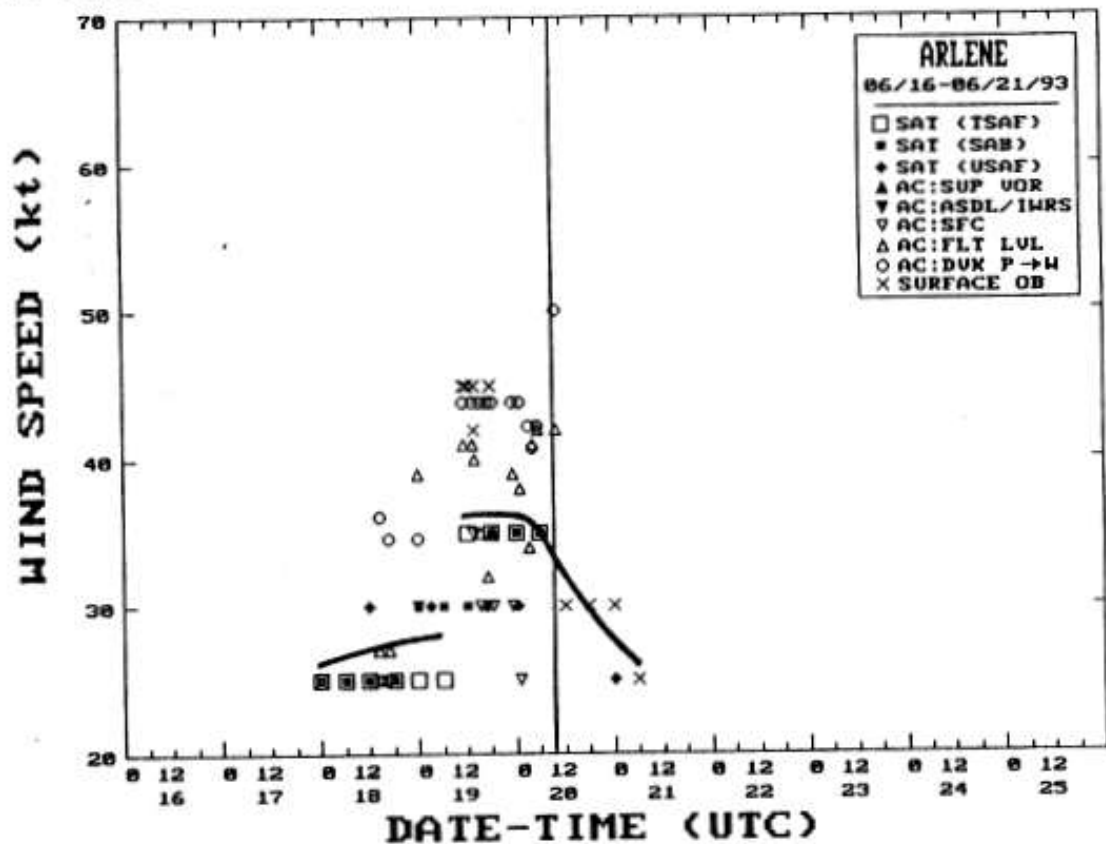


Figure 3. Best track maximum sustained wind speed curve for Tropical Storm Arlene, June 1993. Not all aircraft observations are a sampling of the maximum wind speed. X indicates surface observation or analysis. Vertical line denotes landfall. Dual curves explained in text.

Table 2a. Tropical Storm Arlene selected surface observations, June 1993.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)			Storm surge** (ft)	Storm tide** (ft)	Rain (storm total) (in)
	Pressure (mb)	Date/time (UTC)	sustained wind	Peak gust	Date/time (UTC)*			
Texas (a)								
Brownsville WSO (BRO)	1004.0	19/2315	22	28	21/1021			3.18
C. Christi WSO (CRP)	1003.7	20/1116	22	32	20/0821			9.21
Navy Kingsville (NQI)	1002.1	20/1300	25		20/2000			4.14
Navy C. Christi (NGP)	1003.5	20/1056	23	30	20/1256			6.22
Palacios (PSX)	1008.1	19/2352	20	31	19/1851		E4-5	4.35
Victoria Arpt. (VCT)	1008.8	20/0852	18	27	19/2053			4.26
Port Lavaca							4	5.73
Port O'Connor							4	
Indianola							4	
Kingfisher Marina							4	
Bob Hall Pier						1.8	2.6 MSL	
S. end South Padre I.						1.6	2.2 MSL	
Ship reports (u)								
C6KP2 (27.1°N 92.8°W)			45		19/1800			
Commercial platforms (+, u)								
5R0 (28.2°N 93.8°W 120')			45	55	19/1348			
7W2 (28.5°N 92.5°W 95')			45	50	19/1103			
7R8 (28.3°N 92.0°W 102')			40		19/2000			
S58 (28.2°N 90.7°W 120')			40		19/1139			
01T (28.1°N 94.4°W 110')			E40	45	19/1946			
NDBC instruments (b)								
Buoy								
42002 (25.9°N 93.6°W)	1006.3	19/1000	35	45	19/2000			
42020 (27.0°N 96.5°W)	1005.1	19/1300	27	33	19/1300			
42035 (29.2°N 94.4°W)	1009.7	20/1000	30	36	18/1700			
C-MAN								
PTAT2 (27.8°N 97.0°W)			29	37	19/1633			
SRST2 (29.6°N 94.0°W)	1011.3	20/0000	29	33	20/0000			

Table 2a (cont.). Tropical Storm Arlene selected surface observations, June 1993.

- * Time of 1-minute wind speed unless only gust is given.
- ** Storm surge is water height above normal tide level. Storm tide is water height relative to National Geodetic Vertical Datum (NGVD) which is defined as mean sea level in 1929.
- + A more extreme value may have occurred.
- E Estimated.
- MSL Above Mean Sea Level.
- a One-minute averaged wind.
- b NOAA buoys report hourly an 8-min average wind. C-MAN station reports are 2-min average winds at the top of the hour and 10-min averages at other times. More extreme values may have occurred. Contact NDBC for additional details.
- u Unknown averaging period.

Table 2b. Selected rainfall accumulations (inches) associated with Arlene and, over northeast Texas, Louisiana, and Arkansas, a combination of Arlene and a frontal system.

Location	Total	Location	Total	Location	Total	Location	Total
Mexico (18-20 June; some totals incomplete)							
Merida, Yuc.	13.68	San Jose Tecoh, Yuc.	6.94	Teocelo, Ver.	5.55	Briones, Ver.	5.12
Panuco, Ver	7.89	P. Marte Gomez, Tamps.	6.56	Huajusco, Ver.	5.30	Chetumal, Q. R.	5.02
Camargo SJ. 11, Tamps.	7.32						
Texas							
Henderson	14.82	Kirbyville	7.48	San Jacinto Dam	6.15	Houston airport	5.53
Carthage	13.69	Monte Alto	7.35	Cypress	6.14	Nacadoches	5.51
Longview	13.34	Alief	7.34	Concord	6.12	Alto	5.46
Brazoria	11.60	De Quincy	7.32	Portland	6.10	Agua Dulce	5.42
Marshall	11.53	Bay City	7.21	Washington State Park	6.09	Somerville	5.41
San Manuel	11.44	McCook	7.19	Sour Lake	6.09	Berclair	5.37
Robstown	11.25	Papalote	7.10	Sabine Pass	6.03	Cold Spring	5.33
Jacksonville	11.23	Angleton	6.88	Overton	5.99	Hebronville	5.32
Chalk Hill	11.00	Columbus	6.72	Nursery	5.96	Adams Gardens	5.26
Corpus Christi	10.53	Banquette	6.63	Bishop	5.94	Chapman Ranch	5.20
Anahuac	9.87	Mission	6.62	Calallen	5.93	Whitehouse	5.20
Centerville	9.00	Jewett	6.57	Taft	5.89	Beaumont (city)	5.15
Hallsville	8.91	Jaspar	6.49	Humble	5.84	Bryan xix Ne	5.14
Tatum	8.19	Falfurrias	6.48	Refugio	5.74	Weslaco	5.14
Woodlawn	8.10	Dime Box	6.47	Wortham	5.71	Eastham	5.13
Armstrong	8.05	Gladewater	6.32	Edroy	5.70	Tyler	5.06
Palastine	7.96	Deweyville	6.30	Easterly	5.69	New Caney	5.06
Raymondville	7.95	BPT	6.26	Post Oak	5.67	Crockett	5.03
Longville	7.81	Rincon	6.26	Kountze	5.64	Weiss Bluff	5.03
Goliad	7.59	Engleman Gardens	6.24	Orange	5.59	Realitos	5.01
College Station	7.55	Midway	6.17	Conroe	5.53		
Louisiana							
Lake Charles	12.01	De Ridder (5N)	5.84				
Shreveport	11.46	Old Town Bay	5.80				
Jennings	7.54	Mooringsport	5.70				
Abbeville	7.10	Oil City	5.40				
Harleton	6.92	Karnack	5.19				
Keithville	6.46						
Jefferson	6.29						
Arkansas							
Lewisville	5.02						

Table 3. Watch and warning summary, Tropical Storm Arlene.

Date/Time(UTC)	Action	Region
19/1200	Tropical Storm Warning issued	Brownsville to Matagorda, Texas
20/1200	Tropical Storm Warning discontinued	Brownsville to Matagorda, Texas

Table 4. Watch and warning lead times for landfall sites during Tropical Storm Arlene. Lead time refers to time lapsed from advisory to landfall.

Location	Type	Lead Time (hours)
Padre Island	Tropical Storm Watch	not issued
	Tropical Storm Warning	21

Table 5. Chances of the center of Tropical Storm Arlene passing within 65 miles of listed locations by date and time (EDT) indicated; probabilities in percent with X for less than 2 percent.

ADVISORY ISSUE TIME: 17/11PM 18/5AM 18/11AM 18/5PM 18/11PM
 PROBABILITY END TIME: 20/8PM 21/2AM 21/8AM 21/2PM 21/8PM

MMCZ 205N 869W	2	X	X	X	X
MMSO 238N 982W	16	18	21	19	17
MMTM 222N 979W	16	15	18	16	9
MMTX 210N 974W	15	12	13	13	4
MMVR 192N 961W	10	6	5	7	X
MMFR 185N 926W	6	4	2	3	X
MMDM 210N 897W	8	5	2	X	X
BURAS LA	2	2	X	X	X
NEW ORLEANS LA	2	3	X	X	X
NEW IBERIA LA	4	5	3	2	X
PORT ARTHUR TX	5	7	5	5	2
GALVESTON TX	7	10	7	8	4
FREEPORT TX	8	11	9	9	6
PORT O CONNOR TX	10	13	11	12	11
CORPUSCHRISTI TX	11	15	13	15	15
BROWNSVILLE TX	15	19	18	19	24
GULF 28N 89W	3	2	X	X	X
GULF 28N 91W	5	5	3	2	X
GULF 28N 93W	8	9	7	6	3
GULF 28N 95W	10	12	10	11	9
GULF 27N 96W	13	16	14	15	17
GULF 25N 96W	17	21	21	21	31
GULFPORT MS	X	2	X	X	X

ADVISORY ISSUE TIME: 19/5AM 19/5AM 19/11AM 19/5PM 19/11PM
 PROBABILITY END TIME: 22/2AM 22/2AM 22/8AM 22/2PM 22/8PM

MMSO 238N 982W	21	X	5	4	2
MMTM 222N 979W	8	X	X	X	X
MMTX 210N 974W	2	X	X	X	X
PORT ARTHUR TX	X	X	2	3	2
GALVESTON TX	3	2	5	7	6
FREEPORT TX	4	5	9	10	10
PORT O CONNOR TX	8	19	18	18	19
CORPUSCHRISTI TX	13	34	33	28	38
BROWNSVILLE TX	25	54	99	99	99
GULF 28N 93W	3	X	2	3	2
GULF 28N 95W	7	16	12	13	11
GULF 27N 96W	17	99	99	99	65
GULF 25N 96W	54	99	99	99	5

ADVISORY ISSUE TIME: 20/5AM
 PROBABILITY END TIME: 23/2AM

FREEPORT TX	4
PORT O CONNOR TX	28
CORPUSCHRISTI TX	99
BROWNSVILLE TX	99
GULF 28N 95W	2
GULF 27N 96W	36