

Preliminary Report  
Tropical Storm Debby  
9-11 September 1994

Edward N. Rappaport  
National Hurricane Center  
17 October 1994

Tropical Storm Debby lasted only two days, but locally heavy rain and gusty winds from the cyclone and its remnants led to the deaths of nine people near its track across the eastern Caribbean Sea and adjacent islands.

a. Synoptic History

Debby formed from a westward-moving tropical wave that entered the eastern tropical Atlantic on the 4th of September. Satellite pictures showed the system to be quite large on the 6th and, a day later, indicated several clusters of strong convection with cloud-top temperatures lower than  $-80^{\circ}\text{C}$ . The wave was then located about midway between Africa and the Lesser Antilles islands.

The amount and intensity of deep convection decreased the next day as the system encountered a northwesterly vertical wind shear. The shearing became more westerly and weakened enough for an area of concentrated convection to redevelop when the wave axis was a few hundred miles east of the Lesser Antilles late on the 8th.

At 1200 UTC on the 9th, a ship located about 125 n mi southeast of Barbados reported a light north wind just ahead of the system. About 12 hours later, surface observations and satellite pictures suggested that a surface circulation center was located just west or northwest of Barbados. NOAA was then conducting the first reconnaissance flight into this system. At a flight level of 1500 feet, 50-60 knot winds were measured in a 20-30 n mi wide band that was centered in the vicinity of thunderstorms about 40 n mi north through east of the center. They also estimated surface winds of 50 knots. A few hours later, this part of the system passed over Martinique. Surface observations from Martinique and a nearby ship indicate that, despite the disorganized appearance on satellite pictures, the system was then a tropical storm with one-minute wind speeds of about 60 knots. It is estimated that about 18 hours earlier (at 1200 UTC on the 9th) the system had become a tropical depression with a strong circulation aloft. In the vicinity of Martinique, the winds were efficiently conveyed to the surface by thunderstorms.

The tropical cyclone moved toward the west-northwest at about 17 knots. Westerly vertical wind shear affected the growth of the cyclone by limiting the amount and intensity of thunderstorms and by displacing most of that activity 50-150 n mi to the east of the low-level circulation center. The flight-level and estimated surface wind speeds reported by the Air Force Reserve Hurricane Hunter's near 1200 UTC on the 10th were not as strong as noted earlier, but, just six hours later, returned to magnitudes that

were comparable to those found on the NOAA flight. Meanwhile, the winds at Martinique only slowly abated as the storm receded. Hence, while some fluctuation in surface wind speed likely occurred in association with the variations in deep convection, it is estimated that the surface wind speeds in Debby remained around 50-60 knots through the 10th.

Even though the system continued to produce locally strong winds on the 11th, its circulation became more disrupted by the strong wind shear. By 0200 UTC, a closed circulation center could not be identified by the crew aboard the reconnaissance aircraft. The cyclone is analyzed as degenerating back to a vigorous tropical wave around the 0600 UTC 11 September synoptic hour.

The wave continued to produce locally heavy rain and gusty winds that spread across Hispaniola on the 11th. These conditions advanced westward before diminishing over the northwest Caribbean Sea and adjacent portions of Mexico on the 15th. Satellite pictures indicate that some of the activity could also have spread into the southeastern Gulf of Mexico.

#### b. Meteorological Statistics

The "best track" intensities were obtained from the data presented in Figs. 2 and 3, and in Table 2. Those figures show Debby's estimated central pressure and maximum one-minute wind speed, respectively, versus time.

The 60 knot maximum one-minute surface wind speed at 0600 UTC is primarily based on hourly reports around that time from two observation sites in Martinique. At Le Vauclin, on the southeast coast, 10-min winds of 56 knots with a gust to 85 knots were recorded. At the Morne des Cadets observatory, the maximum 10-min wind was 54 knots with a gust to 84 knots (The maximum one-minute wind speed is usually a little higher than the associated 10-min average). The nearby ship PJRB (name unknown) reported a sustained wind of 44 knots at 0600 UTC, and this likely does not represent the storm's maximum wind at that time.

In addition, the meteorological service of the Dominican Republic reported gusts to 54 knots on the 11th, but this could have come after Debby ceased to exist as a tropical cyclone.

The ship PJRB reported 1000.7 mb at 0600 UTC on the 10th. This pressure is believed to be incorrect. A pressure of 1007.0 mb would have been more appropriate for that time at their location.

An isohyet analysis (not shown) by the meteorological service of Martinique indicates that about one-half of that island had at least 4 inches of rain. The largest total was 7.24 inches at Saint Joseph/Rabuchon.

### c. Casualty and Damage Statistics

A total of four people were killed (in two landslides) and 24 injured in St. Lucia. There was one drowning in Martinique and another (a fisherman) off the southwest coast of Puerto Rico. Three deaths (apparently related to downed power lines) were reported in the Dominican Republic. The deaths in the Dominican Republic occurred on the 11th, possibly after Debby had reverted back to a tropical wave.

The Associated Press indicated that the worst damage occurred in St. Lucia, where rains caused landslides that blocked main roads, and covered the town of Pont St. Jacques (spelling uncertain). Two inches of silt covered the runways at the main international airport. The rains caused floods that washed away hillside shacks, eight bridges, and portions of some roadways. Water was chest-high in the village of Anse La Raye. Debby's winds damaged banana plantations in St. Lucia.

In Martinique, some towns were flooded while wind-felled trees blocked some roads. The banana crop was also damaged in Martinique. About 20,000 residents lost power and schools were closed.

The meteorological service of the Dominican Republic reported that some rivers flooded.

The number of people left homeless in the area affected by Debby was estimated to be in the hundreds.

### d. Forecast and Warning Critique

The data now available suggests that operationally estimated one-minute wind speeds were 10-20 knots too low. Frequently, in the absence of other data, the surface wind is estimated to be around 80% of the 10-s flight level wind speed. The appropriateness of this reduction has been challenged for areas experiencing thunderstorms. In the case of Debby near Martinique, the maximum surface and flight-level wind speeds were both 50-60 knots. This data base also provides an example of how, even on a relatively small island, sampling problems can reduce the accuracy of intensity analyses. Operationally, the highest wind observation on Martinique available to NHC forecasters was the roughly 30 knot 10-min wind and 50 knot gust at Le Lamentin airport.

Debby was a tropical storm for about 24 hours. This is too short a period to allow a meaningful quantitative evaluation of forecast accuracy. The NHC Tropical Cyclone Discussions noted, however, that the Aviation Model persistently forecast decreasing vertical wind shear over the Caribbean in the vicinity of the tropical cyclone. This forecast condition was not realized (nor were similar forecasts in that area this summer.)

The GFDL model has recently shown considerable promise in a

non-operational setting. This year, that model has been run in real-time and has shown a tendency to forecast marked strengthening when no such intensification occurred. For Debby, when the storm's closed circulation was about to dissolve, the GFDL model forecast grossly overestimated the cyclone's intensity. It showed Debby strengthening into a major hurricane along a track where the center passed just south of Haiti, across eastern Cuba and into the Florida Straits (Fig. 4). It was fortunate that this GFDL forecast was incorrect because that period coincided with heightened humanitarian activities in those areas. Beyond the risks that such conditions would normally impose upon the people of that region, thousands of refugees in temporary shelters on land or in small vessels at sea were especially vulnerable.

Table 3 lists the chronology of watches and warnings coordinated by the NHC and representatives of the respective countries. The NHC also contacted officials in Martinique and recommended that tropical storm warnings be issued for that island. Those authorities opted to invoke "heavy rain warnings" but not to issue a tropical storm warning.

Table 4 shows "strike probabilities" for Debby.

Table 1. Preliminary best track, Tropical Storm Debby, 9-11 September 1994.

Date/Time (UTC)	Position Lat. (°N) Lon. (°W)		Pressure (mb)	Wind speed (kt)	Stage
9/1200	13.1	56.8	1011	25	Tropical Depression
1800	13.4	58.3	1010	30	" "
10/0000	13.7	60.2	1010	45	Tropical Storm
0600	14.1	61.6	1006	60	" "
1200	14.6	63.2	1007	55	" "
1800	15.1	64.9	1008	50	" "
11/0000	15.5	66.7	1008	50	" "
0600				45	Tropical Wave
10/0600	14.1	61.6	1006	60	Minimum Pressure
Landfall:					
St. Lucia					
10/0300	14.0	61.0	1007	55	Tropical Storm

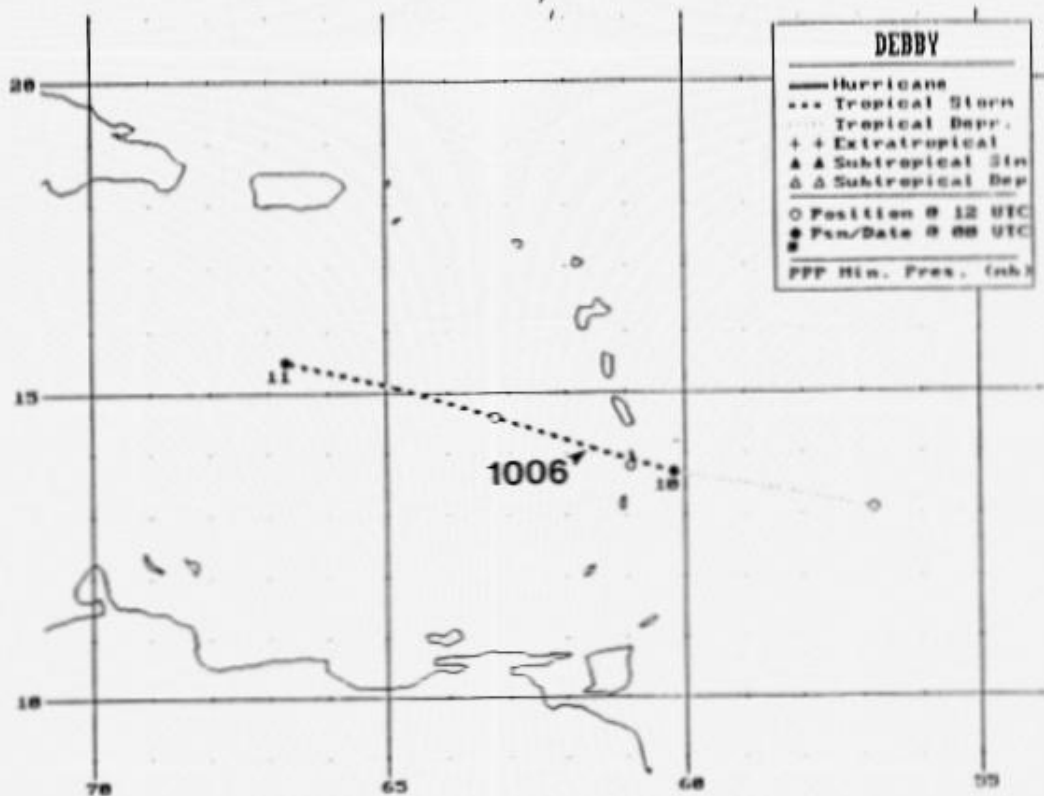


Figure 1. Best track positions for Tropical Storm Debby.

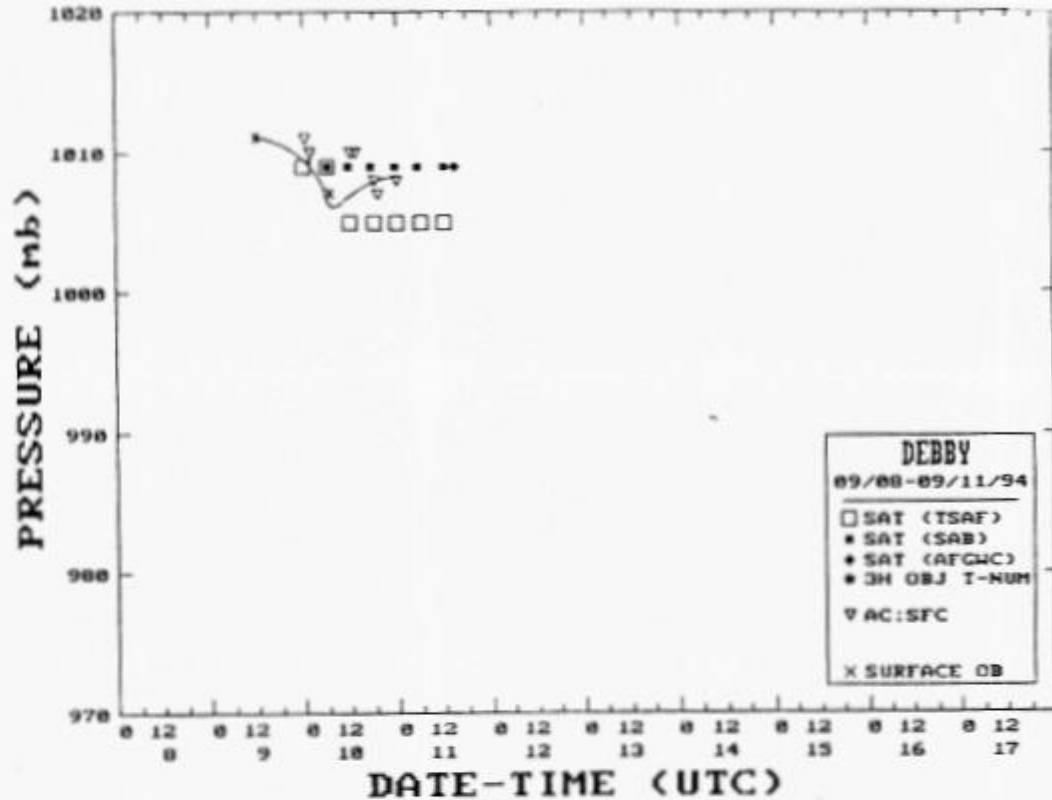


Figure 2. Best track central pressure curve for Tropical Storm Debby, September 1994. X indicates surface analysis or observation.

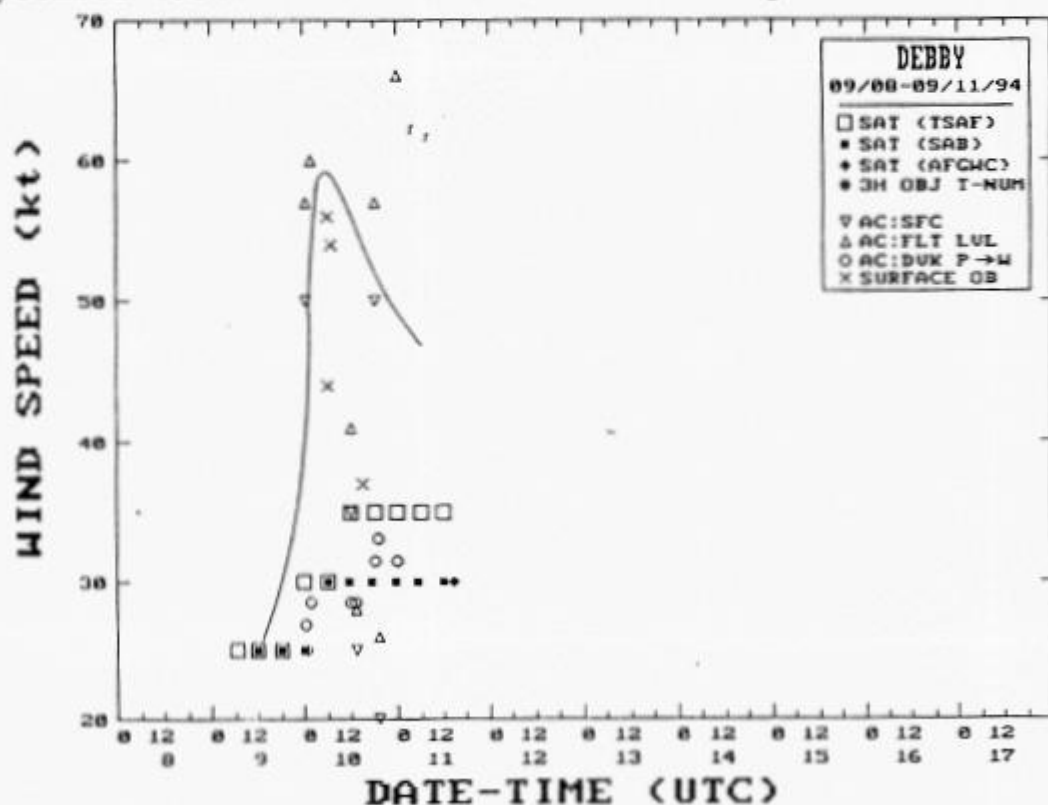


Figure 3. Best track maximum 1-min average wind speed curve for Tropical Storm Debby, September 1994. Not all aircraft observations are a sampling of the maximum wind speed. X indicates surface analysis or observation.



Table 2. Tropical Storm Debby selected surface observations, September 1994.

Location	Minimum sea-level pressure		Maximum surface wind speed (kt)	
	Pressure (mb)	Date/time (UTC)	Sustained wind <sup>a</sup>	Peak gust
<b>Land Sites</b>				
Le Vauclin, Martinique			56	85
Mornes des Cadets, Mart.			54	84
TFFF Le Lamentin, Mart. 1007		10/0600	31	51
TDCF (Dominica)			28	40
TBPB (Barbados)	1009	09/2100, 2200	23	35
Hewanorra, St. Lucia	1008	10/0600	28	35
Vigie, St. Lucia			26	40
				10/0600
				10/0700
				10/0600, 0700, 0800
				10/1200
				10/0400
				10/1145
				10/1200
<b>Ship reports</b>				
ELQNZ (16.3°N 59.7°W)			37	10/1500
PJRB (14.5°N 61.1°W)	1000.7 <sup>b</sup>	10/0600	44	10/0600

<sup>a</sup> Averaging period is 10 minutes, except 1-min at St. Lucia and unknown for ships. Observations are hourly for land sites and 3- or 6-hourly for ships; time is for sustained wind.

<sup>b</sup> Probably was 1007.0 mb.

Table 3. Watch and warning summary (UTC), Tropical Storm Debby.

Date/Time	Action	Region
10/0300	Tropical Storm Warning issued	Barbados, St. Vincent, St. Lucia, Dominica
10/1200	Tropical Storm Warning discontinued	Barbados
10/1500	Tropical Storm Warning issued	Puerto Rico, U. S. Virgin Islands
10/2100	Tropical Storm Warning discontinued	St. Vincent, St. Lucia, Dominica
11/0000	Tropical Storm Warning issued	South coast of Dominican Republic, south coast of Haiti
11/0600	Tropical Storm Warning discontinued	Puerto Rico, U. S. Virgin Islands
11/1500	Remaining Tropical Storm Warnings and Watch discontinued	

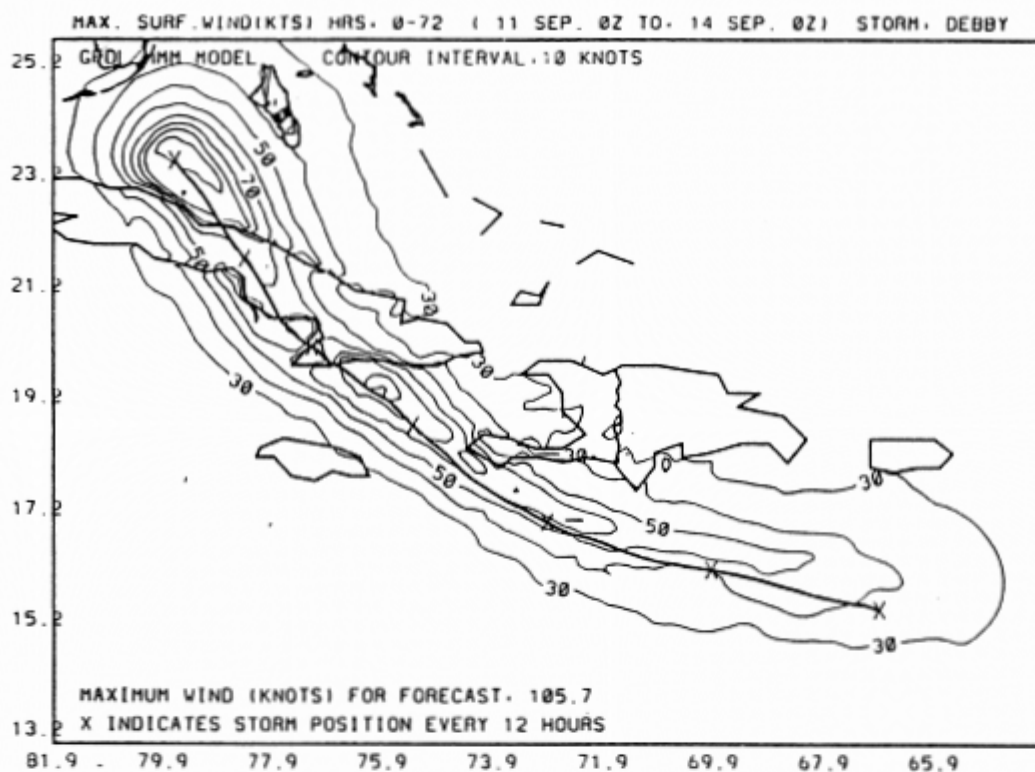


Fig. 4. GFDL model forecast for Tropical Storm Debby at 0000 UTC on 11 September.

Table 4. Chances of the center of Tropical Storm Debby 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:	09/11PM	10/5AM	10/11AM	10/5PM	10/11PM
PROBABILITY	END TIME:	12/8PM	13/2AM	13/8AM	13/2PM	13/8PM
SKPG	125N 717W	10	3	2	2	X
TNCC	122N 690W	10	X	X	X	X
TBPB	131N 595W	99	5	X	X	X
TVSV	131N 612W	99	99	20	X	X
TLPL	138N 610W	99	99	5	X	X
TFFP	146N 610W	99	99	X	X	X
TDPR	153N 614W	92	99	X	X	X
TISX	177N 648W	8	8	X	7	X
TIST	183N 650W	6	3	X	X	X
TJPS	180N 666W	15	22	11	7	2
MDSO	185N 697W	20	29	28	23	13
MDCB	176N 714W	22	29	34	39	51
MTPP	186N 724W	19	25	28	25	31
MTCA	183N 738W	18	22	26	26	35
MKJP	179N 768W	12	14	17	22	26
MKJS	185N 779W	10	12	15	19	23
MWCG	193N 814W	3	4	7	14	15
MUGM	200N 751W	15	18	22	20	21
MUCM	214N 779W	10	13	17	16	18
MUCF	221N 805W	4	7	11	14	16
MUSN	216N 826W	2	3	6	12	13
TJSJ	184N 661W	11	11	2	X	X
MDPP	198N 707W	16	21	20	12	4
MBJT	215N 712W	12	15	14	6	3
MYMM	224N 730W	11	15	16	8	7
MYSM	241N 745W	8	11	13	7	7
MYEG	235N 758W	9	12	16	10	11
MYAK	241N 776W	6	10	14	11	12
MYNN	251N 775W	5	8	12	9	10
MYGF	266N 787W	2	4	8	6	8



Table 4 (cont.). Chances of the center of Tropical Storm Debby 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: 09/11PM	10/5AM	10/11AM	10/5PM	10/11PM
	PROBABILITY END TIME: 12/8PM	13/2AM	13/8AM	13/2PM	13/8PM
MUHA 230N 824W	X	3	7	12	13
TFFR 163N 615W	X	5	X	X	X
MUAN 219N 850W	X	X	2	9	9
MHNJ 165N 859W	X	X	X	2	2
MNPC 141N 834W	X	X	X	2	X
SKSP 126N 817W	X	X	X	2	X
MMCZ 205N 869W	X	X	X	5	5
ST CROIX VI	8	8	X	7	X
ST THOMAS VI	6	3	X	X	X
SAN JUAN PR	11	11	2	X	X
PONCE PR	15	22	11	7	2
MARATHON FL	2	4	8	11	12
MIAMI FL	2	4	8	9	10
W PALM BEACH FL	X	3	7	7	8
FT PIERCE FL	X	2	5	5	7
COCOA BEACH FL	X	2	3	4	5
KEY WEST FL	X	3	7	11	12
MARCO ISLAND FL	X	2	6	8	10
FT MYERS FL	X	2	5	7	9
DAYTONA BEACH FL	X	X	2	3	4
VENICE FL	X	X	3	6	8
TAMPA FL	X	X	2	5	6
CEDAR KEY FL	X	X	X	3	4
ST MARKS FL	X	X	X	2	3
APALACHICOLA FL	X	X	X	2	3
PANAMA CITY FL	X	X	X	2	2
GULF 29N 85W	X	X	X	3	4
GULF 29N 87W	X	X	X	2	3
GULF 28N 89W	X	X	X	2	2
PENSACOLA FL	X	X	X	X	2
JACKSONVILLE FL	X	X	X	X	2

ADVISORY ISSUE TIME: 11/5AM  
 PROBABILITY END TIME: 14/2AM

MDSD 185N 697W	4
MDCB 176N 714W	53
MTPP 186N 724W	31
MTCA 183N 738W	40
MKJP 179N 768W	29
MKJS 185N 779W	25
MWCG 193N 814W	16
MUGM 200N 751W	24
MUCM 214N 779W	20
MUCF 221N 805W	17
MUSN 216N 826W	15
MDPP 198N 707W	2
MBJT 215N 712W	2
MYMM 224N 730W	5
MYSM 241N 745W	6
MYEG 235N 758W	11
MYAK 241N 776W	13
MYNN 251N 775W	10
MYGF 266N 787W	8
MUHA 230N 824W	14
MUAN 219N 850W	10
MHNJ 165N 859W	2
MNPC 141N 834W	2
MMCZ 205N 869W	5
MARATHON FL	13
MIAMI FL	11

Table 4 (cont.). Chances of the center of Tropical Storm Debby 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: 11/5AM  
PROBABILITY END TIME: 14/2AM

W PALM BEACH FL	9
FT PIERCE FL	7
COCOA BEACH FL	6
KEY WEST FL	13
MARCO ISLAND FL	11
FT MYERS FL	10
DAYTONA BEACH FL	4
VENICE FL	9
TAMPA FL	7
CEDAR KEY FL	5
ST MARKS FL	3
APALACHICOLA FL	4
PANAMA CITY FL	3
GULF 29N 85W	5
GULF 29N 87W	4
GULF 28N 89W	3
PENSACOLA FL	2
JACKSONVILLE FL	2
BURAS LA	2
MMMD 210N 897W	2

---