Preliminary Report
Hurricane Dennis
24 August - 7 September 1999

Jack Beven
National Hurricane Center
11 January 2000

Dennis was a larger-than-average western Atlantic hurricane that was erratic in both track and intensity. Although it never made landfall as a hurricane, it affected the North Carolina coast with hurricane force winds, heavy rains, prolonged high surf, and beach erosion. Dennis also produced tropical storm force winds over portions of the Bahamas.

a. Synoptic History

The origin of Dennis can be traced to a tropical wave that moved off the coast of Africa on 17 August. The system moved westward with little significant weather until 21 August, when associated shower activity increased a few hundred miles northeast of the Leeward Islands. A low-level circulation developed over the next two days as convective organization increased. An investigative flight by the Air Force Reserve Hurricane Hunters failed to find a surface circulation on the 23rd. However, the aircraft data indicated a circulation was present at 850 mb. Later surface observations showed a closed circulation, and it is estimated that Tropical Depression Five formed at 0000 UTC 24 August about 190 n mi east of Turks Island (Table 1 and Figure 1). Reconnaissance data and ship reports indicated further intensification, and the depression became Tropical Storm Dennis at 1200 UTC the same day.

The initial structure was unusual. Dennis was at the east-southeast end of an elongated trough that extended to southern Florida. This and upper-level westerly shear caused an asymmetric pattern of convection and tropical storm force winds, with both confined to the eastern semicircle on 24-25 August. Despite the shear, the cyclone intensified unsteadily and reached hurricane strength early on the 26th.

The unusual structure may have also affected the cyclone's motion. Dennis initially moved at 9 to 12 kt, but slowed to an erratic 3 kt on 25 August as steering currents weakened due to a mid-latitude trough passing to the north. At one time that day, the center appeared to re-form eastward along the trough axis. Once Dennis reached hurricane strength, it began a more steady northwestward motion near or over the eastern Bahamas. This motion continued into the 28th.

Westerly shear persisted, preventing significant strengthening until late on 27 August. After the shear decreased, Dennis reached a peak intensity of 90 kt on the 28th and maintained that intensity until early on the 30th. Even at peak intensity, Dennis never consolidated into a classic tightly-wound hurricane. The eye was 30 to 40 miles wide, and on several center fixes the Hurricane Hunters did not report an eye. The radius of maximum winds was as large as 70 to 85 nm on the 29th and 30th.

A second mid-latitude trough caused Dennis to turn gradually northward on 28-29 August,

which was followed by acceleration to the east-northeast on 30th and 31th. This turn kept the center about 60 miles south of the North Carolina coast. The east-northeast motion continued until the trough passed Dennis on the 31st. At that time, steering current collapsed and the cyclone slowed to an erratic drift about 110 n mi east of Cape Hatteras, NC. The erratic motion would last into 2 September.

During this time, Dennis became involved with the cold front associated with the mid-latitude trough. A combination of vertical shear and cool dry air entraining into the circulation decreased the convection and weakened the cyclone. Dennis weakened to a tropical storm on 1 September, and on the 1st and 2nd may have been as much a subtropical or extratropical cyclone as a tropical cyclone. Despite the lack of convection, surface observations indicate maximum sustained winds were near 45 kt during 2 September. Some of these winds were due to the combination of Dennis and a strong surface ridge north of the front, which caused 34 kt or greater winds as far north as the New Jersey coast.

A large westerly ridge over the eastern United States forced Dennis southward late on 2 September. This motion toward warmer water probably aided a deep convective burst on the next day. Later that day, Dennis turned northwest toward the North Carolina coast as the ridge moved east into the Atlantic. This motion continued on the 4th along with re-intensification. Dennis was just below hurricane strength when it made landfall over the Cape Lookout National Seashore just east of Harkers Island, NC at 2100 UTC that day. Dennis continued inland and weakened to a depression on the 5th over central North Carolina. Even in dissipation, Dennis continued to move erratically. Figure 1 shows that the cyclone followed a zig-zag course northward for the rest of its life. Dennis became extratropical on the 7th and was absorbed into a larger low on the 9th.

b. Meteorological Statistics

Table 1 shows the best track positions and intensities for Dennis, with the track plotted in Figure 1. Figures 2 and 3 depict the curves of minimum central sea-level pressure and maximum sustained one-minute average "surface" (10 m above ground level) winds, respectively, as a function of time. These figures also contain the data on which the curves are based: aircraft reconnaissance and dropsonde data from the Air Force Reserve Hurricane Hunter and NOAA, satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Synoptic Analysis Branch (SAB) of the National Environmental Satellite Data and Information Service (NESDIS), and the Air Force Weather Agency, and estimates from synoptic data.

1. Wind and Pressure Data

The Hurricane Hunters flew 24 missions into Dennis and made 81 center fixes, and NOAA research aircraft provided three additional fixes during various research missions. The maximum reported wind was 110 kt (at 700 mb) at 2002 UTC 28 August. While taking 90% of this wind would suggest a maximum sustained surface wind of 99 kt, dropsonde observations at that time do not support that high of a surface wind. The minimum observed central pressure observed from dropsondes was 962 mb at 0350 and 0543 UTC on 30 August. A 959 mb pressure was estimated from 700 mb data at 1017 UTC on the 30th, (Figure 2), but is believed to be too low. The Hurricane

Hunters also measured 71 kt winds (at 850 mb) and a 984 mb pressure just before Dennis made landfall on 4 September. These data indicate Dennis was a 60 kt tropical storm at landfall.

Dennis' path brought it near the eastern Bahamas on 27-28 August. The only official report of tropical storm force winds in the Bahamas was from the Coastal Marine Automated Network (C-MAN) station at Settlement Point, Grand Bahama, which reported 34 kt sustained winds with gusts to 46 kt at 0030 UTC 29 August. (This and other available surface observations are summarized in Table 2.) However, reports relayed to the NHC through amateur radio operators indicated sustained winds of up to 60 to 65 mph with gusts of 70 to 75 mph in the Abaco island group. Reported pressures were as low as 976 mb as the western part of the eye passed over the Abacos around 0700 to 1000 UTC on the 28th. While these observations are significant, their reliability is uncertain. Therefore, they are not included in Table 2.

Dennis tracked parallel to the Florida and Georgia coasts, with tropical storm force winds remaining mostly offshore. The only reported tropical storm force wind was a 41 kt gust at the St. Augustine, FL C-MAN station. The core of Dennis passed just east of NOAA buoy 41010 on 29 August, which reported 57 kt sustained winds with gusts to 72 kt at 0500 UTC and a minimum pressure of 980.2 mb at 0750 UTC.

Dennis' first pass near the coast of the Carolinas on 30 August caused sustained tropical storm force winds with gusts to hurricane force in coastal North Carolina and gusts to tropical storm force in coastal South Carolina from Charleston northward. The maximum reported sustained winds were 53 kt with gusts to 77 kt at Oregon Inlet at 2030 UTC. It is not clear whether sustained hurricane force winds affected the coast. There are no observations of such winds, and analyses from the Hurricane Research Division suggests they stayed offshore. However, gusts to 96 kt at Wrightsville Beach and 85 kt at Hatteras Village (Table 2) suggest that sustained hurricane force winds may have occurred along the coasts of New Hanover and Dare counties. Sustained hurricane force winds of 81 kt with gusts to 97 kt were measured at the Frying Pan Shoals C-MAN station (145 ft elevation) at 0945 UTC 30 August, with a minimum pressure of 977.2 mb at 0900 UTC.

The landfall of Dennis on 4 September produced tropical storm force winds over portions of eastern North Carolina and coastal southeastern Virginia. Langley Air Force Base VA, reported 45 kt sustained winds with gusts to 66 kt at 2330 UTC, while Cherry Point Marine Corp Air Station NC, reported 41 kt sustained winds with gusts to 53 kt at 2005 UTC.

The large circulation of Dennis also affected shipping over a portion of the western Atlantic. Table 2a shows the available ship observations of tropical storm force or greater winds. The maximum ship-observed winds were 65 kt from the **Zim U.S.A.** at 0900 UTC 30 August, while the lowest observed pressure was 987.3 mb from the **Hoegh Dene** at 1800 UTC 4 September. Observations from the **Sealand Crusader** on 24 August were important in determining that the pre-Dennis wave had developed into a depression.

2. Storm Surge Data

Few detailed observations of storm surge are available from areas affected by Dennis (Table

2). Storm tides of 3 to 5 ft above normal were reported along much of the North Carolina coast on both 30 August and 4 September. Areas along the Neuse River reported tides of 8 to 10 ft above normal tide level on 30 August, while areas along the Pamlico River reported similar values on 4 September. Portions of the South Carolina and southeastern Virginia coast experienced 2 to 4 ft above normal tides during Dennis, while amateur radio reports from the Bahamas indicate tides 1 to 3 ft above normal as the eye passed over the Abacos.

Since Dennis meandered off the North Carolina coast for several days, the above normal tides were unusually prolonged. This led to extensive beach erosion along portions of the North Carolina and southeastern Virginia coasts.

3. Rainfall data

Dennis affected the mid-Atlantic states twice within a week, and other weather systems affected the region during the same period. This makes determination of storm total rainfall in that area difficult. Table 2 shows the storm total rainfalls for Dennis, including the best estimates in North Carolina and Virginia. The maximum reported total was 19.13 inches at Ocracoke NC, with 6 to 10 inches reported elsewhere over portions of eastern North Carolina. Rainfalls of 3 to 6 inches occurred elsewhere over eastern North Carolina, extreme eastern South Carolina, and over portions of southeastern Virginia. Rainfalls were generally 1 to 3 inches elsewhere over eastern South Carolina and less than an inch in Florida and Georgia.

Dennis and the other weather systems contributed to a wet period over portions of the mid-Atlantic states. Table 2b shows 11-day rainfall totals of 6 inches or more ending at 1200 UTC 8 September. The heaviest rainfalls were observed over eastern North Carolina and central Virginia. While this rainfall broke a prolonged dry spell in the area, it also set the stage for the severe flooding caused by Hurricane Floyd two weeks later.

Official rainfall data from the Bahamas indicates a maximum total of 4.00 inches at Cat Island. Heavier amounts likely occurred on Eleuthera and in the Abaco group near the eye of Dennis.

4. Tornadoes

One tornado was reported with Dennis on 4 September. This F2 tornado in Hampton VA caused an estimated $7 million damage and 15 injuries, 6 of them serious.

c. Casualty and Damage Statistics

Four deaths reported in Florida were related to high surf spawned by the hurricane. No deaths are known due to winds, rains, storm tides or tornadoes associated with Dennis.

In the United States, the Property Claims Services Division of the Insurance Services Office reports insured losses due to Dennis totaled $60 million in North Carolina and Virginia. To determine the total property damage, a two to one ratio is applied to the insured property damage based on comparisons done in historical hurricanes. Press reports indicate that agricultural losses in

North Carolina and Virginia were $37 million. Combining these reports gives a total estimated damage from Dennis of $157 million.

There are no damage reports available from the Bahamas as of this time.

d. Forecast and warning critique

Table 3 shows the track forecast errors during Dennis for the official NHC track forecast and a selection of objective guidance models. The official forecasts were generally quite good with errors of about 60% to 70% of the long term average. The official forecasts also were better than the objective guidance with two exceptions: The United Kingdom Meteorological Office global model (UKM) was slightly better than the official forecast at all time periods, and the barotropic model LBAR was slightly better at 12 and 24 hours. It should the noted that the UKMI, which is the interpolated UKM track forecast available to hurricane forecasters in real time, was slightly worse than the official forecast at all time periods. There were two periods with worse than average official track forecasts. The first was on 24 August, as the poorly-organized Dennis consistently moved slower than forecast. The second on was 28 August, when the motion parallel to the coast on 30-31 August was poorly forecast.

While intensity forecast errors were also better than the long term average, there was a significant positive bias which is counter to the 10-year average. This occurred due to forecasts on 28-30 August which predicted Dennis to remain a hurricane when it actually weakened to a tropical storm. Three consecutive forecasts during this time overforecasted the 72 hour intensity by 50 kt.

Table 4 shows the watches and warnings that were issued for Dennis. Due to the somewhat erratic motion near the Bahamas, hurricane warnings were issued for Eleuthera and the Abacos 40 hours before the eye passed over the Abacos. While tropical-storm force winds did not occur over land south of Charleston, SC, they were present over the Florida, Georgia, and South Carolina coastal waters. Hurricane warnings for the North Carolina coast on 29 August had less than the normally-desired 24 hour lead time. However, these were issued in anticipation that Dennis' large size and track just offshore would cause hurricane conditions along the coast and not in anticipation of a landfall. Hurricane warnings were also issued for the North Carolina coast on 4 September in anticipation of Dennis regaining hurricane strength before landfall. These proved to be unnecessary.

Acknowledgments:

Much of the data in this report was provided by the local National Weather Service forecast offices in Miami, Melbourne, Jacksonville, Charleston, Wilmington, Morehead City, and Wakefield. Buoy and C-MAN station data was provided by the National Data Buoy Center. James Franklin created the wind and pressure plots.

Table 1. Best track, Hurricane Dennis, 24 August - 7 September 1999

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
24/0000	21.5	67.7	1009	30	tropical depression
24/0600	22.0	68.9	1009	30	"
24/1200	22.4	70.0	1009	35	tropical storm
24/1800	22.7	70.9	1009	40	"
25/0000	22.8	71.5	1008	40	"
25/0600	23.0	71.9	1007	40	"
25/1200	23.2	72.1	1004	45	"
25/1800	23.4	72.3	1000	55	"
26/0000	23.6	72.5	998	60	"
26/0600	23.8	73.1	995	65	hurricane
26/1200	24.1	73.6	995	65	"
26/1800	24.4	74.0	990	70	"
27/0000	24.8	74.4	993	65	"
27/0600	25.2	75.0	988	65	"
27/1200	25.6	75.5	988	65	"
27/1800	25.9	75.9	987	65	"
28/0000	26.1	76.2	982	70	"
28/0600	26.5	76.7	976	75	"
28/1200	27.1	77.0	973	85	"
28/1800	27.7	77.3	969	90	"
29/0000	28.3	77.7	969	90	"
29/0600	29.0	77.9	970	90	"
29/1200	29.9	78.4	971	90	"
29/1800	30.8	78.4	967	90	"
30/0000	31.9	78.1	964	90	"
30/0600	32.8	77.6	962	90	"
30/1200	33.6	76.5	965	85	"
30/1800	34.3	74.8	966	85	"
31/0000	34.9	73.6	971	80	"
31/0600	35.1	72.9	977	80	"
31/1200	35.2	72.8	983	75	"
31/1800	35.1	73.3	984	70	"
01/0000	35.2	73.6	986	60	tropical storm
01/0600	35.0	73.4	987	55	"
01/1200	35.4	73.5	989	50	"
01/1800	35.5	73.8	988	50	"
02/0000	35.4	73.7	988	50	"
02/0600	35.2	73.6	989	45	"

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
02/1200	35.1	73.7	989	45	"
02/1800	34.8	73.9	990	45	"
03/0000	34.2	74.0	989	45	"
03/0600	33.6	74.1	989	45	"
03/1200	33.2	73.9	988	45	"
03/1800	33.0	73.8	987	50	"
04/0000	33.1	74.0	987	50	"
04/0600	33.3	74.5	986	55	"
04/1200	33.9	75.3	986	55	"
04/1800	34.5	76.0	986	60	"
05/0000	35.0	76.8	985	50	"
05/0600	35.5	77.7	989	35	"
05/1200	36.1	78.8	994	30	tropical depression
05/1800	36.2	79.4	998	25	"
06/0000	36.2	79.9	1000	25	"
06/0600	36.4	80.1	1004	20	"
06/1200	37.0	79.9	1005	20	"
06/1800	37.7	79.5	1008	20	"
07/0000	38.5	78.5	1009	20	"
07/0600	40.8	77.0	1008	20	"
07/1200	42.7	77.7	1007	20	"
07/1800	43.5	77.7	1006	20	extratropical
08/0000	43.5	76.5	1006	20	"
08/0600	44.0	75.8	1006	20	"
08/1200	44.9	74.8	1006	20	"
08/1800	45.5	75.6	1005	20	"
09/0000					lost identity

30 /0600	32.8	77.6	962	90	minimum pressure
Landfalls:					
28/0700	26.6	76.8	976	75	Abaco Islands, Bahamas
04/2100	34.8	76.5	984	60	Cape Lookout National Seashore, NC

Table 2.
Hurricane Dennis selected surface observations, 24 August - 7 September 1999.
(Incomplete pending further data from NDBC)

Location	Pres. (mb)	Date/ Time (UTC)	Sust. Wind (kts)[a]	Peak Gust (kts)	Date/ Time (UTC)[b]	Storm Surge (ft)[c]	Storm Tide (ft)[d]	Total Rain (in)
Bahamas								
Cat Island								4.00
North Carolina								
Alligator Bridge[#]			48	56	30/1100			
Atlantic (Texas Tech tower, 30 ft)	992.6	30/1351	48	75	30/1532			
Beaufort	984.8	04/2049	33	45	04/1823			
Beaufort (Texas Tech tower, 33 ft)	992.8	30/1302	52	75	30/1103			
Blockade Runner				72				
Brunswick Cnty Airport				61	30/0810			
Brunswick Power Plant			50[g]		30/0456			
Calabash				35				1.57
Carolina Beach				66	30/0710			
Castle Hayne (Oxychem)				54	30/1100			
Castle Hayne (SW)			35	67	30/0900			
Cherry Point MCAS	986.5	04/2355	41	53	04/2005			9.24
Delco			28	57	30/1200			
East Waccamaw				34	30/1100			0.98
Elizabeth City	1003.8	04/2313	34	45	30/1654			7.01
Elizabethtown				37				
Flemington			39	68	30/0900			
Greenville				43	05/0140			
Harkers Island Bridge				76	30/1230			
Hatteras Inlet			50[$]	64	30/19300			
Hatteras Village				85	30/1515			
Jacksonville	994.2	05/0235		41	30/0835			
Kingston				37	04/2250			
Kure Beach				58	30/0740			
Kure Beach (Federal Point)				71	30/0530			
Manteo				52	30/1635			
New Bern	986.8	05/0000	35	46	30/1056			3.35
New River	993.9	04/2126	33	50	30/0956			5.75
Newport	985.1	04/2115		54	30/1204			9.89
North Topsail Beach			44[$]	65	30/1240			
Oak Island			46	62	30/0800			
Ocean Isle				49	30/0559			
Ocean Isle (Tubbs Inlet)				46	30/0753			
Ocracoke Island[#]	995.1	31/0740	35[$]	58	31/0220			19.13
Oregon Inlet			53[$]	77	30/2030			
Oriental							6-8	
St. James								6.00
Shallotte				60	30/0700			
Shallotte Inlet				60	30/0730			
Southport (Elementary)				49				9.01
Southport (Marina)								13.50
Southport (Pilot Boat Dispatch)				60	30/0743			
Washington				41	30/1520			
Whiteville				37				1.97
Wilmington Airport	996.1	0953	42	53	30/0607			4.73
Wilmington (Battleship North Carolina)				66	30/0530			6.70
Wilmington (College RD/ Oleander DR)				46				8.75

Wilmington (Corning)				60	30/1200		
Wilmington (Eastwood RD/ Military Cutoff)				44	30/0650		6.60
Wilmington (Masonboro Loop)				37			
Wilmington (New Hanover EOC)			51	76	30/0800		
Wilmington (WECT-TV)				46			5.07
Wrightsville Beach				96	30/0444		
Wrightsville Beach Fire Dept.				73	30/0630		
South Carolina							
Charleston Harbor						2.0	
Charleston WFO			29	40	29/2050		1.22
Murrells Inlet							2.88
Myrtle Beach (Pavilion)				45	30/0600		
N. Myrtle Beach			29	42	30/0732		1.65
Virginia							
John Kerr Dam							3.38
Norfolk Airport	1006.1	05/0551	37	46	30/1651		3.30
Langely AFB	1007.1		45	66	04/2332		
Newport News	1006.5		28	39	04/2332		3.32
Norfilk NAS	1006.5						2.85
Oceana NAS	1006.5						2.90
Portsmouth							5.75
Richmond	1006.5	05/0754					2.18
Roanoke Rapids			27	35	30/1214		
Sewells Point						3.0	
Wakefield							4.59
Wallops Island			33	40	30/1717		
NOAA Buoys and C-MAN Stations							
Buoy 41001	976.0	31/0400	48[$]	63	30/2300		
Buoy 41002	997.6	30/1100	43[$]	59			
Buoy 41004	990.5	30/0300	54[$]	72	30/0330		
Buoy 41008	1003.9	29/2000	31	43	29/1700		
Buoy 41009[#]	1001.3	29/0900	29	37	29/0700		
Buoy 41010	980.2	29/0750	57	72	29/0500		
Buoy 44014	1002.3	30/2000	43	53	30/2100		
Drifting Buoy 41650[#]	1009.8	27/0000	45		27/1200		
Drifting Buoy 41651[#]	1010.8	25/2100	42		25/2100		
Cape Lookout NC (CKLN7)	986.5	04/2000	60	79	30/1400		
Chesapeake Bay VA (CHLV2)	1006.2	05/0600	49[$]	56	30/2100		
Duck NC (DUCN7)	1005.6	04/2300	56	65	30/2000		
Folly Beach SC (FBIS1)	1001.6	30/0100	24	35	30/0000		
Frying Pan Shoals NC (FPSN7)	977.2	30/0900	81[$]	97	30/0945		
Settlement Point, BI (SPGF1)	1002.6	28/2200	34[$]	46	29/0030		
St. Augustine FL (SAUF1)	1004.9	29/1100	27	41	29/1355		

[a] Standard NWS ASOS and C-MAN averaging period is 2 min; buoys are 8 min.
[b] Date/time is for sustained wind when both sustained and gust are listed.
[c] Storm surge is water height above normal astronomical tide level.
[d] Storm tide is water height above NGVD.
[e] Estimated.
[$] 10 min average
[g] 100 ft tower, 15 min average
[#] Incomplete record

Table 2a. Ship observations of tropical storm or greater winds associated with Hurricane Dennis, 24 August - 7 September 1999.

Ship	Date/Time (UTC)	Lat. (°N)	Lon. (°W)	Wind dir/speed (deg/kt)	Pressure (mb)
Sealand Crusader	24/0600	21.0	67.0	130/35	1011.5
Iver Express	24/1800	23.2	74.6	010/39	1012.0
Jo Sypress	26/1500	25.9	73.0	120/39	1012.5
Nomzi	27/0000	25.9	74.3	090/44	1010.0
Nomzi	27/0300	25.9	74.0	090/45	1010.0
Nomzi	27/0600	26.0	73.7	070/40	1011.0
Star Hidra	28/2100	30.1	77.5	050/40	1005.0
Morelos	28/2100	26.2	74.4	170/34	1007.0
Torm Freya	29/0000	30.2	75.5	100/35	1005.0
Nedlloyd Holland	29/0000	27.8	79.2	340/42	1002.0
Star Hidra	29/0000	30.0	77.0	050/41	1004.0
Nedlloyd Holland	29/0300	28.7	79.9	340/39	1002.2
Star Hidra	29/0300	29.5	76.4	090/55	1001.0
Torm Freya	29/0600	29.5	74.8	150/48	1005.0
Star Hidra	29/0600	29.8	76.5	120/56	999.3
Star Hidra	29/0900	29.7	76.4	150/56	999.5
Star Hidra	29/1200	29.6	76.2	160/55	1000.5
Star Hidra	29/1500	29.3	76.1	180/46	1003.0
Torm Freya	29/1800	28.3	74.9	190/46	1007.0
Zim U.S.A.	29/2100	32.0	75.0	140/38	1006.0
Star Hidra	29/2100	28.8	77.1	210/37	1005.5
Zim U.S.A.	30/0000	32.0	75.1	160/40	1004.0
Zim U.S.A.	30/0300	32.0	75.3	160/50	1002.0
Zim U.S.A.	30/0600	31.8	75.5	180/65	999.0
OOCL Fair	30/0600	33.4	74.3	150/40	1005.0
Zim U.S.A.	30/0900	32.3	75.0	180/65	1000.0
OOCL Fair	30/0900	32.7	74.3	180/50	1002.0
Zim U.S.A.	30/1200	31.4	75.7	250/50	1002.5
SHIP	30/1200	36.9	75.0	040/40	1014.5
Zim U.S.A.	30/1500	31.5	76.3	270/50	1006.0
OOCL Fair	30/1500	32.1	74.6	210/50	1002.0

Ship	Date/Time (UTC)	Lat. (°N)	Lon. (°W)	Wind dir/speed (deg/kt)	Pressure (mb)
Inspiration	30/1800	35.8	71.9	080/50	1006.0
OOCL Fair	30/1800	32.0	75.0	260/55	1006.0
Inspiration	30/2100	35.6	72.6	090/55	1002.5
Barbet Arrow	31/1200	32.5	71.5	240/40	1009.2
Stonewall Jackson	31/1200	33.5	71.7	230/55	1003.5
Sealand Performance	31/1200	35.1	70.1	160/45	1005.0
Barbet Arrow	31/1800	32.4	72.3	250/40	1015.0
Edyth L.	31/1800	34.8	75.1	310/55	1005.7
Stonewall Jackson	31/1800	33.4	72.7	250/45	1007.0
Sealand Performance	31/1800	33.7	69.8	230/40	1009.5
Stonewall Jackson	02/0000	33.5	75.1	300/36	1010.0
Trojan Star	02/0000	36.8	70.7	110/38	1010.1
V2PE1	02/0600	33.9	72.2	220/40	1008.0
Shanghai Senator	02/0900	37.6	75.1	040/35	1011.0
V2PE1	02/1200	35.0	72.1	200/43	1005.2
OOCL Friendship	02/1800	34.1	74.7	300/45	999.2
V2PE1	02/1800	35.6	72.9	140/42	1004.5
OOCL Friendship	02/2100	34.1	73.5	200/45	993.6
V2PE1	03/0600	36.3	75.3	040/40	1010.5
Chemical Pioneer	03/1500	34.3	76.3	320/40	1004.7
Chemical Pioneer	03/1800	34.7	75.8	340/35	1004.7
Hoegh Dene	04/0600	33.1	77.3	100/39	1005.3
Hoegh Dene	04/1200	33.8	76.4	360/37	1000.0
Hoegh Dene	04/1500	34.1	76.0	110/39	992.5
Hoegh Dene	04/1800	34.4	75.6	150/40	987.3
Mette Maersk	04/1800	35.4	74.4	110/45	1002.9
Mette Maersk	04/2100	35.8	73.6	120/37	N/A
Hoegh Dene	05/0000	35.5	75.0	140/35	1003.8

Table 2b. Eleven day rainfall totals ending at 1200 UTC 8 September 1999. Data courtesy of the National Climatic Data Center

Station	Rainfall (in)	Station	Rainfall (in)
North Carolina			
Aurora	10.68	Greenville	7.66
Jacksonville	10.54	Edenton	7.33
Cherry Point	10.18	Wilsonville	7.11
Hatteras	9.30	Enfield	7.01
Apex	8.87	Kinston	6.80
Raleigh/Durham	8.46	Rougemount	6.69
Elizabeth City	8.17	Rocky Mount	6.53
Goldsboro (GSB)	8.04	Butner	6.50
Goldsboro	7.76	Arcola	6.34
Neuse	7.72	New Bern	6.09
Wilson	7.69	Oxford	6.07
Pennsylvania			
Lochiel	7.23	Elimsport	6.90
Williamsport	7.00	Loyalsockville	6.90
South Carolina			
Myrtle Beach	6.02		
Virginia			
Allisonia	13.82	Fincastle (DAEV2)	7.03
Buchanan	12.91	Mauretown	7.00
Front Royal (HOGV2)	12.86	Lovingston (LOVV2)	6.87
Roanoke (WITV2)	10.33	Front Royal (LIMV2)	6.76
Montebello	9.40	Lovingston (BRNV2)	6.68
Copper Hill (COPV2)	8.31	Strasburg	6.57
Fincastle (TIKV2)	7.63	Waynesboro	6.52
Copper Hill (COHV2)	7.62	Springcreek	6.50
Alberta	7.49	Roanoke (FOTV2)	6.44
Winterpock	7.33	South Boston	6.41
Algoma	7.11	Glasgow	6.28
Mathews	7.10	Pedlar Mills	6.20
Luray	7.09		

Table 3. Preliminary track forecast evaluation for Hurricane Dennis - heterogeneous sample. Errors in nautical miles for tropical storm and hurricane stages with number of forecasts in parentheses. Numbers in bold italics represent forecast which were better than the official forecast.

Forecast Technique	Period (hours)				
	12	24	36	48	72
CLIP	44 (46)	92 (44)	150 (42)	209 (40)	360 (36)
GFDI	40 (38)	75 (36)	110 (34)	148 (32)	213 (29)
GFDL*	40 (36)	69 (34)	100 (32)	136 (30)	209 (27)
LBAR	***31*** (46)	***61*** (44)	99 (42)	137 (40)	217 (36)
AVNI	53 (42)	100 (40)	139 (38)	175 (35)	220 (26)
AVNO*	46 (40)	93 (37)	134 (35)	163 (32)	213 (22)
BAMD	35 (45)	65 (44)	102 (41)	144 (39)	212 (35)
BAMM	43 (46)	84 (44)	128 (42)	168 (40)	260 (36)
BAMS	56 (46)	111 (44)	169 (42)	230 (40)	343 (36)
NGPI	48 (44)	76 (42)	108 (40)	133 (38)	184 (30)
NGPS*	46 (23)	77 (22)	100 (21)	133 (20)	173 (16)
UKMI	41 (41)	68 (39)	96 (38)	118 (37)	161 (33)
UKM*	***33*** (23)	***61*** (22)	***82*** (21)	***106*** (20)	***147*** (18)
A90E	39 (45)	73 (43)	100 (41)	138 (39)	228 (35)
A98E	38 (40)	73 (38)	110 (36)	151 (34)	240 (30)
A9UK	37 (22)	73 (21)	108 (20)	147 (19)	274 (17)
NHC Official	34 (46)	63 (44)	90 (42)	112 (40)	160 (36)
NHC Official 10-Year Average (1989-1998)	48 (2005)	89 (1790)	128 (1595)	164 (1410)	242 (1107)

* Output from these models was unavailable at time of forecast issuance.

Table 4. Watch and warning summary, Hurricane Dennis, 24 August- 7 September 1999.

Date/Time (UTC)	Action	Location
24/1500	Tropical Storm Warning Issued	Bahamas...Turks and Caicos Islands and SE Bahamas
24/1500	Tropical Storm Watch Issued	Central Bahamas.
25/0900	Hurricane Watch and Tropical Storm Warning Issued	Central Bahamas.
25/0900	Hurricane Watch Issued	Northwest Bahamas.
26/0900	Tropical Storm Warning Discontinued	Bahamas...Turks and Caicos Islands and SE Bahamas.
26/1500	Hurricane Warning Issued	Central Bahamas. Northwest Bahamas...Eleuthera and the Abacos.
27/0300	Tropical Storm Warning Issued	Northwest Bahamas...New Providence, Grand Bahama, and the Berry Islands.
27/0900	Hurricane Warning Issued	Northwest Bahamas...remainder.
27/1500	Hurricane Watch Issued	Florida....Sebastian Inlet to Fernandina Beach.
27/1500	Hurricane Warning Discontinued	Central Bahamas...including Andros and New Providence Islands.
27/2100	Tropical Storm Warning Issued	Florida...Sebastian Inlet to Flagler Beach.
28/0900	Hurricane Warning Discontinued	Bahamas...Eleuthera and the Berry Islands.
28/2100	Hurricane Warning Discontinued	Bahamas...Abacos and Grand Bahama Islands.
29/0300	Hurricane Watch Issued	N of Savannah, GA to Surf City, NC.
29/0300	Hurricane Watch Discontinued	Florida...Sebastian Inlet to Fernandina Beach.
29/0900	Tropical Storm Warning Issued	N of Savannah, GA to Surf City, NC.
29/0900	Hurricane Watch Issued	North Carolina...Surf City to Cape Hatteras.
29/1500	Tropical Storm Warning Issued	North Carolina...Surf City to Cape Hatteras.
29/1500	Tropical Storm Watch Issued	N of Cape Hatteras to Cape Charles Light, VA.
29/2100	Hurricane Watch upgraded to Hurricane Warning	Little River Inlet, SC to Oregon Inlet, NC...including Pamlico Sound.
29/2100	Tropical Storm Warning Issued	Oregon Inlet, NC to Chincoteague, VA...including Abermarle Sound and southern Chesapeake Bay south of New Point Comfort.
30/0300	Hurricane Watch and Tropical Storm Warning Discontinued	Edisto Beach, SC to Savannah, GA.
30/0900	Hurricane Watch upgraded to Hurricane Warning	Oregon Inlet, NC to North Carolina/Virginia border.

Date/Time (UTC)	Action	Location
30/0900	Gale Warning Issued	Chincoteague, VA to Cape Henlopen, DE.
30/0900	Hurricane Watch and Tropical Storm Warning Discontinued	N of Savannah, GA to Little River Inlet, SC.
30/2100	Hurricane Warning discontinued	South of Cape Lookout, NC to Little River Inlet, SC.
31/0300	Hurricane Warning downgraded to Tropical Storm Warning	Cape Lookout, NC to NC/VA border.
31/0900	Gale Warning issued	Cape Henlopen, DE to Great Egg Inlet, NJ.
01/0300	Tropical Storm Warning and a Hurricane Watch issued	Surf City, NC to Chincoteague, VA...including Pamlico and Ablemarle Sounds and southern Chesapeake Bay south of New Point Comfort.
01/1500	Hurricane Watch discontinued	Surf City, NC to Chincoteague, VA...including Pamlico and Ablemarle Sounds and southern Chesapeake Bay south of New Point Comfort.
02/0600	Gale Warning discontinued	Fenwick Island, DE to Cape Henlopen, DE.
02/0600	Gale Warning issued	Chincoteague, VA to Fenwick Island, DE.
02/1500	Tropical Storm Warning discontinued	North of Cape Charles Light, VA to Chincoteague, VA South of Cape Lookout, NC to Surf City, NC.
02/2100	Tropical Storm Warning discontinued	Southern Chesapeake Bay south of New Point Comfort.
03/0300	Tropical Storm Warning discontinued	Cape Charles Light, VA to NC/VA border.
03/0900	Tropical Storm Warning discontinued	Oregon Inlet, NC to NC/VA border.
03/2100	Tropical Storm Watch issued	Oregon Inlet, NC to NC/VA border...including Ablemarle Sound. Cape Lookout, NC to Surf City, NC.
04/0900	Tropical Storm Warning issued	N of Oregon Inlet, NC to the NC/VA border...including Ablemarle Sound. S of Cape Lookout, NC to Surf City, NC.
04/1500	Tropical Storm Warning upgraded to Hurricane Warning	NC/VA border to Surf City, NC...including Pamlico and Ablemarle Sounds.
04/1500	Tropical Storm Warning issued	N of NC/VA border to Chincoteague, VA...including Chesapeake Bay south of Smith Point.
04/2100	Tropical Storm Warning issued	Entire Chesapeake Bay...including the Tidal Potomac.
04/2100	Gale Warning issued	N of Chincoteague, VA to Great Egg Inlet, NJ.
05/0100	Hurricane Warning downgraded to Tropical Storm Warning	NC/VA border to Surf City, NC...including Pamlico and Ablemarle Sounds.
05/0900	Tropical Storm Warning discontinued	NC/VA border to Surf City, NC...including Pamlico and Ablemarle Sounds.

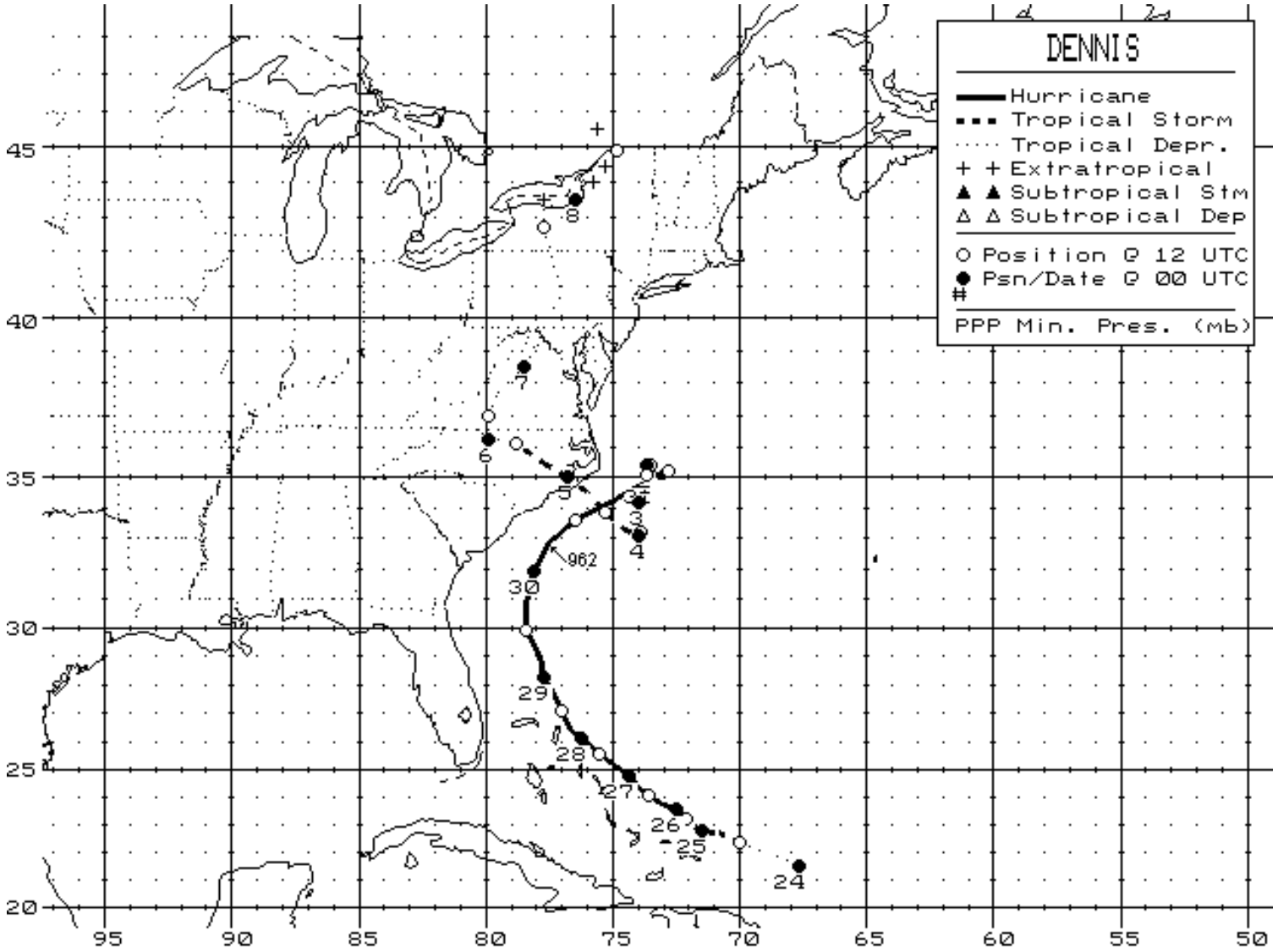

Figure 1. Best track for Hurricane Dennis, 24 August - 7 September 1999.

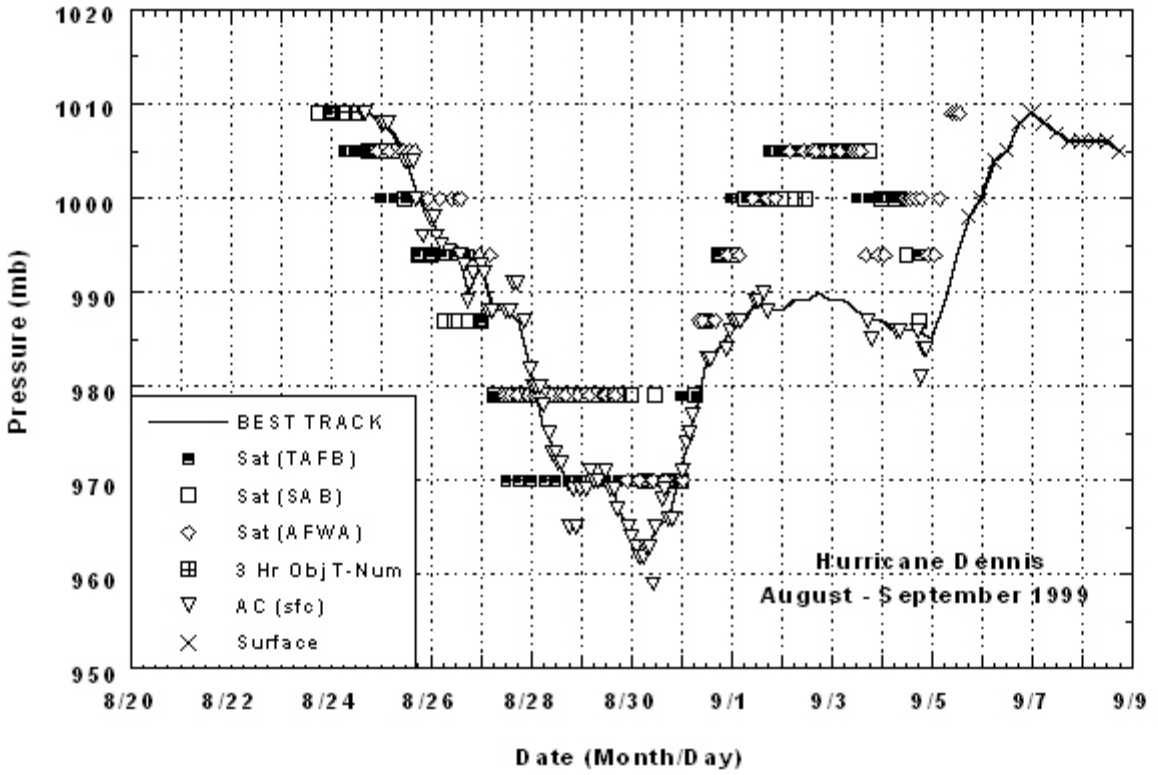

Figure 2. Best track minimum central pressure curve for Hurricane Dennis, 24 August - 7 September 1999.

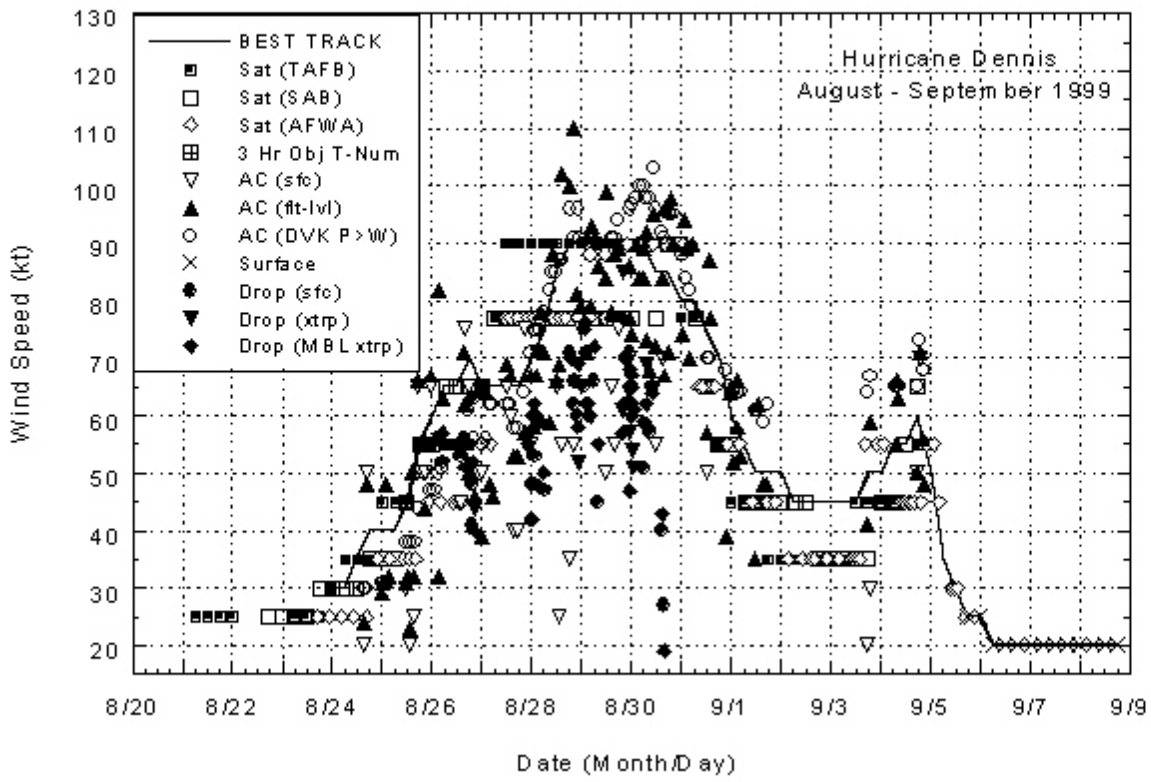

Figure 3. Best track maximum sustained 1-minute 10 meter wind speed curve for Hurricane Dennis, 24 August - 7 September, 1999.