

Preliminary Report
Hurricane Felix
8 - 25 August 1995

Max Mayfield and Jack Beven
National Hurricane Center
19 November 1995

a. Synoptic History

A tropical wave moved off the African coast on 6 August. Satellite imagery indicated that it quickly displayed evidence of a circulation as it moved toward the west. The post-analysis "best track" (Fig. 1) shows that the disturbance became Tropical Depression Seven about 400 n mi west-southwest of the Cape Verde Islands at 0000 UTC 8 August when loosely organized deep convection increased. Best track position, central pressure and maximum one-minute sustained wind speed are listed for every six hours in Table 1.

The depression strengthened into Tropical Storm Felix later on the 8th and followed a west-northwestward track at 15-20 knots for the next three days. Based on satellite intensity estimates, Felix reached hurricane strength at 0000 UTC 11 August while centered about 500 n mi east-northeast of the Leeward Islands. Reports from reconnaissance aircraft indicated rapid strengthening from the time of the first eye penetration near 1200 UTC on the 11th through the 12th. Maximum sustained surface winds of 120 knots are estimated to have occurred near 1800 UTC 12 August. A well-defined eye was visible in satellite imagery at this time.

Felix moved northwestward on 12 August, and then turned more toward the north and started to weaken on 13 August. Two factors likely contributed to the weakening: 1) Felix went through a concentric eyewall cycle, and 2) wind shear increased over the system when Felix's upper-level anticyclone didn't remain centered over the lower-level cyclonic circulation. Aircraft data on the 13th when Felix was centered 300 to 400 n mi south-southeast of Bermuda indicated a large wind field with several wind maxima and no tight center. These characteristics would persist for much of the remainder of the storm's life.

Felix's northward turn was due to a large deep-layer trough over the western Atlantic. The trough split as Felix approached, with one part moving northeastward and filling and the other moving southward to the southwest of the hurricane. The resulting steering pattern allowed Felix to resume a general northwestward motion by 15 August, with this motion persisting into the next day. This track took the storm center within 65 n mi of Bermuda and toward the North Carolina coast.

The split in the trough resulted in increased ridging over the western Atlantic that appeared to be strong enough to drive Felix into the eastern United States. However, a small weakness remained between 70° and 75°W as indicated by Air Force and NOAA reconnaissance data on the 16th. Felix turned northward into the weakness and almost stalled late on the 16th. It then moved slowly northeastward on 17 August. A second westerly trough failed to pick up the storm on 18-19 August, and Felix performed an anticyclonic loop offshore as the trough bypassed the tropical cyclone. The hurricane accelerated northward on 20 August and northeastward on 21 August in response to a third trough.

During 17-19 August, Felix had a 50-70 n mi wide eye on aircraft radar and rather weak convection in satellite imagery. Despite this, the storm maintained 65-70 knot sustained winds and a central pressure near 970 mb. It is possible that this structure was due to cooler, drier air entering the circulation at low and mid levels. Felix dropped below hurricane strength on 20 August as it moved over colder water and shearing again increased.

Felix became extratropical about 300 n mi east-northeast of Newfoundland on 22 August. The extratropical cyclone was tracked across the North Atlantic between Scotland and Iceland and then toward Norway.

On a historical note, the threat of Hurricane Felix postponed Bermuda's scheduled vote for independence. Ironically, the first inhabitants at Bermuda were survivors of a hurricane-caused shipwreck on the island in 1609. Their stories helped inspire Shakespeare's writing of *The Tempest*.

b. Meteorological Statistics

Figures 2 and 3 show the curves of minimum central pressure and maximum one-minute wind speed, respectively, versus time, along with the observations on which they are based. The satellite estimates were provided by the NESDIS Synoptic Analysis Branch (SAB), the NHC's Tropical Analysis and Forecast Branch (TAFB, formerly TSAF as in figures) and the Air Force Global Weather Central (AFGWC).

U.S. Air Force Reserve aircraft provided a total of 70 operational center fixes on Felix. The 24 missions and approximately 280 flying hours of reconnaissance on this hurricane are both records for an Atlantic tropical cyclone. The maximum winds of 143 knots from a flight-level of 700 mb were measured at 1254 UTC 12 August. The minimum central pressure reported by aircraft was 930 mb at 2328 UTC 12 August, and it is likely that the pressure was somewhat lower during the previous 10 hours when there were no aircraft measurements. In addition to the Air Force Reserve reconnaissance, two NOAA aircraft flew a research mission on 16 August.

During most of the 15th and 16th, the minimum central pressure hovered between 965 and 970 mb, which would normally be consistent with 85-100 knot surface winds. However, maximum flight-level winds reported by reconnaissance aircraft were only 65 to 75 knots at 850 and 700 mb. This would suggest a minimal hurricane at most. The rawinsonde at Bermuda indicated 55 knot surface winds with 80 knots at 400 feet. Because a large component of these winds were probably brought to the surface in strong convective bands, the maximum sustained surface winds are estimated at 70-75 knots during this time.

Numerous ship reports were received in the vicinity of Felix and were helpful in defining the extent of tropical storm force winds. Table 2 lists 81 ship reports of at least tropical storm force winds in association with the cyclone.

Bermuda reported a minimum pressure of 988.1 mb and maximum sustained winds of 55 knots with gusts to 70 knots at 0000 UTC 15 August as the center of Felix passed about 65 n mi to the south-southwest. No sustained tropical storm force winds were reported by U.S. land stations. Wind gusts to 37 knots were reported from the NWS office at Buxton, North Carolina at 2058 UTC 16 August and at 0102 UTC 17 August while the hurricane was centered about 125 n mi to the east.

The eye of Felix passed over NOAA buoy 41001 located at 34.7°N 72.6°W, about 150 n mi east of Cape Hatteras, near 1600 UTC 16 August. The buoy reported a 970.4 mb pressure at this time with light winds. A 10-minute average wind of 53 knots and gusts to 66 knots were reported earlier by the buoy near 1200 UTC.

Rain bands associated with Hurricane Felix remained offshore of the U.S. coast.

Although the strong winds and heavy rains did not directly affect the United States, large swells generated by Felix produced dangerous surf conditions including some coastal flooding and rip currents from northeastern Florida to New England. Isolated areas of severe beach erosion occurred along the New Jersey coast, but the most significant beach erosion occurred on the Outer Banks of North Carolina. Highway 12 on the Outer Banks was flooded with sand and ocean overwash at times of high tides. Beach nourishment occurred in some coastal areas of North Carolina to the southwest of the Outer Banks.

c. Casualty and Damage Statistics

A total of 8 deaths were confirmed in association with Felix, 3 off the North Carolina coast and 5 off the New Jersey coast. All of these fatalities were a result of drowning.

Although there was considerable beach erosion, little significant property damage occurred.

d. Forecast and Warning Critique

During the time when Felix was a tropical storm or hurricane, the mean official track forecast errors were 38 (54 cases), 75 (52 cases), 112 (50 cases), 147 (48 cases) and 227 (44 cases) n mi at 12, 24, 36, 48 and 72 hours, respectively. Although these errors were lower than the long-term averages from the previous ten years, there were some large individual errors including five over 500 n mi at 72 hours. Three of these large errors occurred while Felix was between Bermuda and North Carolina and were primarily a result of not correctly anticipating the decrease in forward speed on 13-15 August. The other two cases occurred while Felix was beginning the anticyclonic loop well off the U.S. coast and resulted from not correctly anticipating the beginning and amount of the acceleration toward the northeast. On average, the official forecast errors were similar to the track prediction model errors. The GFDI, BAMB and BAMD 72-hour mean forecast errors were only slightly lower than the official forecast errors.

Some large 72 hour intensity forecast errors (35 to 45 knots) occurred. The intensity forecasts did not correctly indicate the rapid strengthening on the 11th and 12th, nor the weakening thereafter. Other relatively large underforecasts (35 to 40 knots) resulted from incorrectly forecasting Felix to weaken along a track that moved the hurricane inland.

Table 3 lists the coastal watches and warnings issued during Felix. Although Felix never made landfall in the United States, some of the official forecasts and several of the track prediction models indicated this possibility. If Felix had continued on the northwestward track onto the mid-Atlantic coast, considerable damage and loss of life were possible. Given the NHC track forecasts, time required for evacuations from coastal areas and barrier islands, and the limitations in track forecasting, the watches and warnings were deemed necessary and were well-coordinated with appropriate NWS offices and the U.S. Navy.

Acknowledgments

Some information in this report was provided by NWS offices in the watch and warning areas. Position estimates during the extratropical stage were provided by the Hydrological Prediction Center.

Table 1. Preliminary best track, Hurricane Felix,
8 - 25 August 1995.

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
08/0000	14.3	30.8	1010	30	Trop. Depression
0600	14.7	32.5	1008	30	" "
1200	15.0	34.4	1007	30	" "
1800	15.5	36.4	1005	35	Tropical Storm
09/0000	15.7	38.3	1004	40	" "
0600	16.0	40.2	1003	45	" "
1200	16.2	41.9	1001	45	" "
1800	16.6	43.7	1000	45	" "
10/0000	17.0	45.6	998	50	" "
0600	17.5	47.4	996	55	" "
1200	18.0	49.1	993	60	" "
1800	18.4	50.8	991	60	" "
11/0000	18.9	52.4	987	65	Hurricane
0600	19.6	53.9	980	70	"
1200	20.4	55.4	972	80	"
1800	21.3	56.5	965	90	"
12/0000	22.1	57.8	955	100	"
0600	22.9	59.0	943	110	"
1200	23.6	60.2	932	115	"
1800	24.3	61.0	929	120	"
13/0000	25.1	61.6	930	115	"
0600	25.9	61.9	937	105	"
1200	26.6	62.3	942	100	"
1800	27.4	62.3	947	95	"
14/0000	28.2	62.5	948	90	"
0600	29.0	62.9	954	80	"
1200	29.9	63.4	962	80	"
1800	30.7	64.1	962	75	"
15/0000	31.3	65.1	962	75	"
0600	31.9	66.2	964	75	"
1200	32.5	67.4	968	70	"
1800	33.1	68.8	965	70	"
16/0000	33.5	70.1	963	70	"
0600	34.0	71.3	966	70	"
1200	34.6	72.4	968	70	"
1800	34.8	72.7	970	70	"
17/0000	35.3	72.9	968	65	"
0600	35.6	72.9	971	65	"
1200	36.1	72.7	972	65	"
1800	36.5	72.2	973	65	"
18/0000	36.8	71.5	973	65	"
0600	37.1	70.7	971	65	"
1200	37.1	69.9	970	65	"
1800	36.9	68.9	971	70	"
19/0000	36.6	68.1	970	70	"
0600	36.1	67.8	970	70	"
1200	35.7	67.5	971	70	"

1800	35.4	67.4	973	70	"
20/0000	35.1	67.5	976	65	"
0600	35.0	67.9	979	60	Tropical Storm
1200	35.4	68.2	982	60	" "
1800	35.9	68.3	985	60	" "
21/0000	36.6	67.8	986	60	" "
0600	37.7	67.0	988	55	" "
1200	39.0	66.1	989	50	" "
1800	40.6	63.3	988	50	" "
22/0000	42.5	59.8	987	50	" "
0600	44.5	55.8	986	50	" "
1200	46.8	50.8	985	50	" "
1800	49.0	46.0	985	50	Extratropical
23/0000	50.8	40.5	985	50	"
0600	53.5	35.5	985	50	"
1200	56.0	34.0	986	50	"
1800	58.0	31.0	987	50	"
24/0000	59.5	26.0	988	50	"
0600	60.0	20.0	988	45	"
1200	60.0	14.0	989	40	"
1800	60.0	7.5	990	35	"
25/0000	61.5	1.0	992	35	"

12/1800	24.3	61.0	929	120	Minimum Pressure
---------	------	------	-----	-----	------------------

TABLE 2. Ship reports of 34 knots or higher winds associated with Hurricane Felix.

Tropical Cyclone	Ship Call Sign	Date Mo/Da	Time UTC	Position LatN LonW	Wind (kt) Dir/Speed	Pressure (mb)
FELIX						
	P3ME5	8/11	1800	19.0 61.0	360/43	1014.0
	LAJ04	8/12	0600	27.6 52.5	230/42	1019.0
	P3ME5	8/12	1200	20.7 64.1	320/43	1014.0
	P3ME5	8/12	1800	21.2 65.1	300/49	1014.5
	LADQ4	8/13	0600	23.3 61.6	220/42	1006.0
	LADQ4	8/13	1200	23.7 60.5	210/43	1009.0
	LAJ04	8/13	1200	25.0 57.9	140/39	1013.0
	LAJ04	8/13	1800	24.6 58.9	140/50	1010.0
	OYEK2	8/14	0000	38.0 68.9	020/60	1011.0
	KRHZ	8/14	1200	29.2 58.8	150/37	999.9
	Unknown	8/14	1200	31.7 58.0	150/34	1013.7
	ELIG9	8/15	1800	35.1 74.7	020/36	1010.2
	WZJF	8/15	1800	35.7 72.7	010/36	1008.0
	Unknown	8/15	1800	37.4 74.4	050/42	1012.2
	LAVY4	8/16	0000	35.1 73.0	020/34	1003.5
	WZJF	8/16	0000	37.9 73.2	050/52	1001.1
	Unknown	8/16	0000	38.5 72.4	050/58	1010.7
	Unknown	8/16	1200	39.1 68.7	020/39	1013.2
	Unknown	8/16	1800	38.8 68.1	160/39	1014.2
	Unknown	8/16	1800	39.1 70.7	120/47	-
	OXME2	8/17	0000	37.3 72.4	140/47	1000.0
	OXME2	8/17	0600	37.0 71.8	110/46	997.5
	P3ME5	8/17	1200	33.4 69.3	190/58	1015.5
	ELQF6	8/17	1200	35.2 69.2	170/35	1008.0
	OXME2	8/17	1200	36.9 71.5	120/51	992.9
	OXEH2	8/17	1800	35.3 68.4	170/37	1008.5
	ELRE5	8/17	1800	36.0 68.8	180/41	1017.0
	ELQF6	8/17	1800	36.3 69.0	180/35	1006.0
	OXME2	8/17	1800	36.8 71.5	140/60	981.0
	ELPB8	8/17	1800	40.5 61.5	270/47	1014.6

ELRE5	8/18	0000	35.6	68.9	180/45	1013.5
OXME2	8/18	0000	36.5	71.3	240/45	975.0
ELQF6	8/18	0000	37.7	69.7	200/50	997.0
OXME2	8/18	0600	36.0	71.2	240/62	984.5
XCTJ	8/18	0600	33.4	68.4	210/36	1011.0
KXDB	8/18	0600	37.4	67.1	170/35	1099.5
WZJF	8/18	0600	37.6	67.2	140/45	1000.5
ELQF6	8/18	0600	38.1	71.1	090/52	989.0
P3ME5	8/18	1200	32.9	71.5	240/39	1014.0
OXEH2	8/18	1200	34.0	69.8	220/34	1005.0
ELRE5	8/18	1200	34.5	69.4	230/45	1013.0
ELNG6	8/18	1200	35.3	74.3	330/34	-
WMLG	8/18	1200	35.8	61.5	200/34	1015.8
OXME2	8/18	1200	35.9	71.6	280/55	995.0
ELQF6	8/18	1200	37.6	72.5	990/50	1000.0
ELJP8	8/18	1200	39.2	55.5	240/54	1011.0
OXEH2	8/18	1800	34.2	70.8	270/37	1005.0
ELRE5	8/18	1800	34.3	70.3	270/48	1015.0
DICA	8/18	1800	35.0	65.0	190/40	1007.5
WZJF	8/18	1800	35.1	66.0	200/43	1007.0
WMLG	8/18	1800	35.2	62.8	190/37	1012.0
ZHEM7	8/18	1800	35.2	67.3	230/35	998.0
OXME2	8/18	1800	36.3	72.7	330/34	1004.0
ELNG6	8/18	1800	36.9	74.0	350/41	1012.0
ELQF6	8/18	1800	37.3	74.0	350/50	1008.5
ELPB8	8/18	1800	40.1	66.9	- /64	1006.7
VSBT2	8/19	1200	31.7	69.2	240/36	996.0
WMLG	8/19	1200	31.9	65.3	190/36	1009.5
DCIA	8/19	1200	32.5	67.0	220/37	1007.5
ELRE5	8/19	1200	36.0	73.9	010/40	1021.0
VRIM	8/19	1200	36.6	73.2	020/50	1010.7
PJJU	8/19	1200	37.5	72.1	020/37	1010.2
ICBA	8/19	1200	40.5	66.6	090/45	1016.0
VSBT2	8/19	1800	32.5	70.3	270/37	996.0
ZHEM7	8/19	1800	34.0	69.2	- /42	999.5
VRIM	8/19	1800	37.2	72.8	020/53	1012.1
ZHEM7	8/20	0000	34.3	70.3	- /42	1000.3
PJJU	8/20	0600	33.6	69.7	320/35	1003.5
Unknown	8/20	1200	36.5	73.6	070/40	1010.5

VSBT2	8/20	1800	35.5	72.0	320/40	998.5
ELNG6	8/21	0000	34.7	68.9	270/38	-
VSBT2	8/21	0000	36.5	71.8	320/35	998.0
Unknown	8/21	1200	37.3	61.1	200/35	1018.1
VSBT2	8/21	1200	38.6	70.5	320/35	1001.5
Unknown	8/21	1800	37.3	61.2	210/44	1015.5
DQFS	8/22	0000	40.4	49.6	220/35	1024.0
DQFS	8/22	1200	40.1	53.2	230/47	1016.0
3FXW3	8/22	1200	42.1	46.2	210/45	1022.3
Unknown	8/22	1200	42.1	46.2	210/45	1022.3
Unknown	8/22	1200	42.9	51.3	210/35	1009.2
UNRK	8/22	1200	43.1	51.2	200/43	1007.7

TABLE 3. Watch and warning summary, Hurricane Felix.

Date/Time (UTC) /Action	Location
12/1700 Hurricane Watch	Bermuda
13/1500 Tropical Storm Warning	Bermuda
14/0300 Hurricane Warning	Bermuda
15/1200 Hurricane Watch	Edisto Beach, SC to Cape Henlopen, DE including Albemarle and Pamlico Sounds and Chesapeake Bay south of Windmill Point
15/1200 Hurricane Warning replaced with a Tropical Storm Warning	Bermuda
15/1500 Hurricane Warning	North of Little River Inlet, SC to Chincoteague, VA including Albemarle and Pamlico Sounds and Lower Chesapeake Bay from Windmill Point southward
15/2100 Tropical Storm Warning	North of Chincoteague, VA to Manasquan Inlet, NJ including Chesapeake Bay north of Windmill Point and Delaware Bay
16/0600 Tropical Storm Warning discontinued	Bermuda
16/1200 Hurricane Watch discontinued	Little River Inlet, SC southward to to Edisto Beach, SC
16/1500 Hurricane Warning discontinued	South of New River Inlet, NC
17/0300 Tropical Storm Warning replaced with a Tropical Storm Watch	Chesapeake Bay north of Patuxent River
17/0900 Tropical Storm Warning replaced with a Tropical Storm Watch	North of Cape Henlopen, DE to Manasquan Inlet, NJ including Chesapeake Bay from Patuxent River to Windmill Point...and Delaware Bay
17/0900 Tropical Storm Watch discontinued	Chesapeake Bay north of Patuxent River
17/1500 Hurricane Warning replaced with a Tropical Storm Warning and Hurricane Watch	Cape Lookout, NC to Chincoteague, VA including Albemarle and Pamlico Sounds
17/1500 Hurricane Warning replaced with a Hurricane Watch	Chesapeake Bay from Windmill Point southward
17/1500 Tropical Storm Watch discontinued	Chesapeake Bay from Patuxent River to Windmill Point
17/1500 Hurricane Warning discontinued	South of Cape Lookout, NC
18/0000 Hurricane Watch discontinued	Chesapeake Bay south of Windmill Point
18/0300 All Tropical Storm Warnings discontinued	
18/0900 All Hurricane and Tropical Storm Watches discontinued along U.S. mid Atlantic coast	
19/1030 Tropical Storm Watch	Bermuda
20/1800 Tropical Storm Watch discontinued	Bermuda

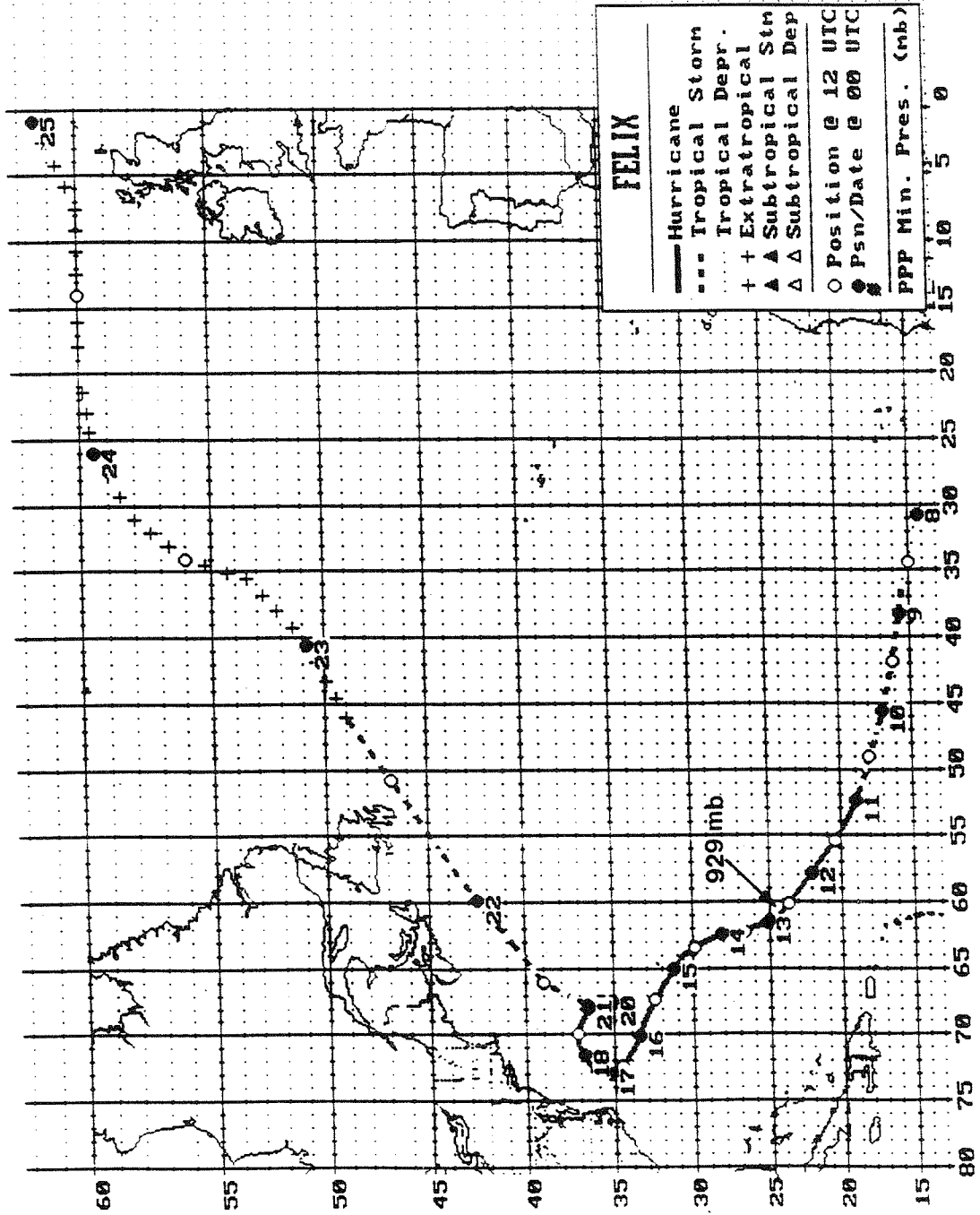


Figure 1. Best track positions for Hurricane Felix, 8 - 25 August 1995.

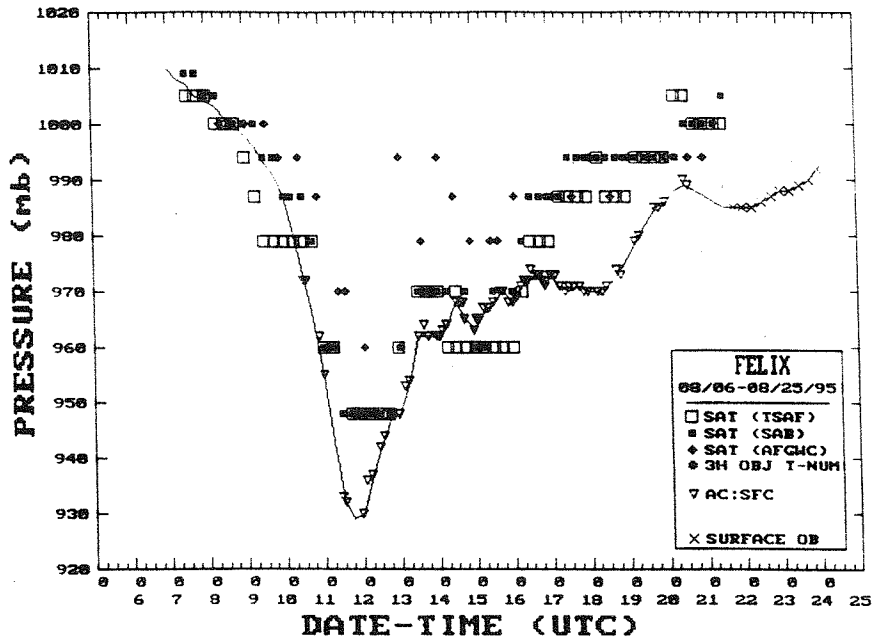


Figure 2. Best track minimum central pressure curve for Hurricane Felix, 1995. X's indicate estimates from surface analyses.

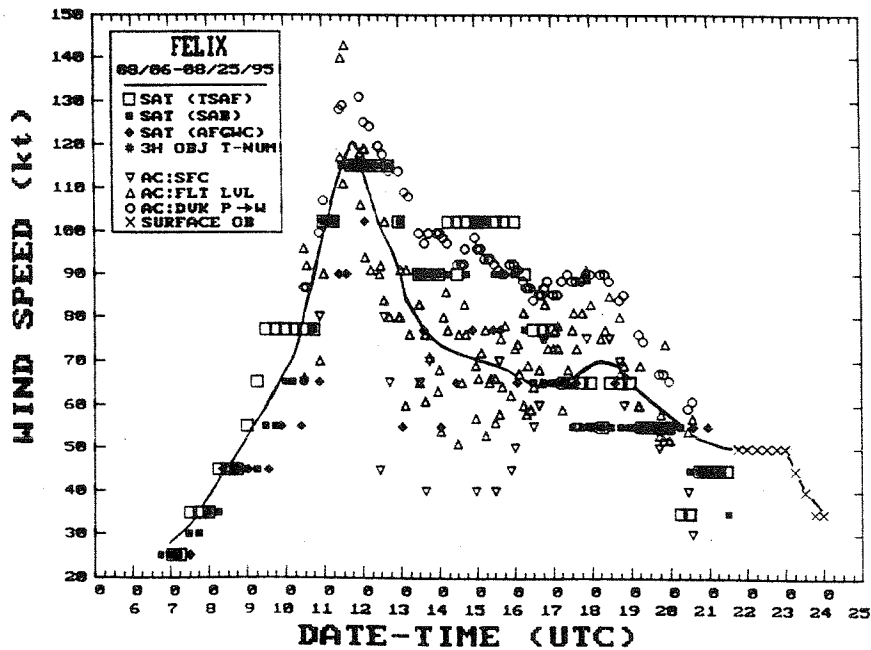


Figure 3. Best track maximum sustained wind speed curve for Hurricane Felix, 1995. Not all aircraft observations are a sampling of the maximum wind. X's indicate estimates from surface analyses.