Preliminary Report
Tropical Storm Josephine
4 - 8 October 1996

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Josephine made landfall in the eastern Apalachee Bay, Florida area as a 60-knot tropical storm.

a. Synoptic History

The origin of Josephine does not appear to be directly related to a tropical wave. On 29-30 September, a front, which had moved over the southwestern Gulf of Mexico, stalled over that area. A broad area of cloudiness and showers was noted over the southwest Gulf beginning around this time. This disturbed weather appears to have been caused mainly by the front, but could also be partially ascribed to a tropical wave which passed over the extreme southern Gulf on 29 September. This wave led to the formation of Hernan in the eastern Pacific. A broad area of low pressure developed near the Bay of Campeche on 1-2 October, but upper-tropospheric winds were only marginally favorable for development, and the associated deep convection was not persistent until the 3rd. The surface circulation became better defined on the 4th, on which day the system received its initial Dvorak classification from the Tropical Analysis and Forecast Branch (TAFB). Meanwhile, the strong pressure gradient between the low and a large high pressure system centered near the Great Lakes began to produce strong winds across the northern Gulf of Mexico.

An Air Force Hurricane Hunter plane was dispatched to the system on the afternoon of the 4th and data from the aircraft indicated that a tropical cyclone, Tropical Depression Ten, had formed. Based on aircraft, surface and satellite data, the estimated time of genesis is 1800 UTC 4 October. The post-analysis "best track" is shown in Table 1 and Figure 1. Initially, steering currents were weak and the depression moved slowly north-northeastward on the 4th and 5th. Southwesterly shearing was present over the system and there was no significant increase in organization until the 6th. Even though the depression did not intensify during the first couple of days of its existence, the strong pressure gradient persisted over the northern Gulf, producing gale to storm force winds over that area. By midday on the 6th, aircraft observations indicated that the central pressure had dropped to 1001 mb. Banding features on satellite images became better defined and it is estimated that the cyclone strengthened into Tropical Storm Josephine at 1800 UTC 6 October.

A strong mid-latitude, deep-layer trough began to dominate the eastern half of the United States, and on the 6th and 7th the tropical storm was steered eastward to northeastward, at an increasing forward speed, on the southeast flank of this trough. Early on the 7th, Josephine strengthened significantly and was nearing hurricane intensity. This development trend proved to be temporary, however, as vertical shear began to increase over the northeast Gulf. Josephine's cloud structure became more asymmetric, with nearly all of the deep convection northeast of the center. The storm's intensity leveled off at 60 knots. The center moved over Apalachee Bay on the evening of the 7th, and crossed the coast in a relatively uninhabited region of north Florida, in Taylor County, at about 0330 UTC on the 8th of October.

Josephine was already beginning to lose its tropical characteristics when it crossed the coast, since the temperature at Keaton Beach dropped about 6°C in one hour shortly after the storm moved inland. The system became an extratropical cyclone by the time it entered Georgia at 0600 UTC 8 October. The cyclone's forward speed increased dramatically, to near 40 knots, and the extratropical low raced northeastward near the U.S. east coast, passing close to Cape Cod at 0600 UTC on the 9th. The low traversed Nova Scotia and Newfoundland on 9-10 October, and then emerged over the north Atlantic. It moved eastward for a day or two, slowing its forward speed. Then the system tracked counter-clockwise within a deep-layer cyclonic flow regime over the northeastern Atlantic on the 12th through the 15th. Finally, the extratropical remnant of Josephine merged with a larger extratropical cyclone in the vicinity of Iceland on 16 October.

b. Meteorological Statistics

Figures 2 and 3 depict the curves of minimum central sea-level pressure and maximum one-minute average "surface" (10 meters above ground level) wind speed, respectively, as a function of time. Also plotted are the observations on which the curves are based, consisting of aircraft reconnaissance data from the U.S. Air Force Reserves (the Hurricane Hunters), Dvorak-technique estimates (from the TAFB, the Synoptic Analysis Branch, and the U.S. Air Force Global Weather Center) using satellite imagery, and fixes from synoptic weather map analyses.

The minimum central pressure reported in Josephine, by the Hurricane Hunters, was 981 mb at 1135 UTC 7 October. Highest flight-level (850 mb) winds near that time were 66 knots. The maximum flight-level wind reported by reconnaissance aircraft was 74 knots at 0050 UTC 8 October. Josephine's maximum surface winds were estimated to be 60 knots from 1200 UTC on the 7th up to landfall 16 hours later. Aircraft observations indicated that, at most, a partial eyewall was present on three center fixes during the above period.

Table 2 lists ship reports of tropical storm force winds associated with Josephine. There were additional reports (not included in this table) of gale to storm force winds from ships over the northern and western Gulf of Mexico that were estimated to be not within the circulation of the tropical cyclone. Table 3 lists selected surface observations from Florida.

Storm surge heights were "significant" from the Tampa area northward to eastern Apalachee Bay. County officials estimated storm tides (storm surge plus astronomical tide) ranged from up to 9 feet in Levy county to 4 to 6 feet in Pinellas and Hillsborough Counties, and 3 feet as far south as Lee County. These tides produced widespread flooding of roads, dwellings, and businesses.

According to reports from National Weather Service Offices, at least 16 tornadoes occurred in association with Josephine over northern and central Florida. These caused mostly minor damage, primarily to trees. One tornado, however, had a 7 mile long, 400 yard wide track across Edgewater in Volusia County. It severely damaged 30 homes, while 100 others had minor damage.

Rainfall amount of up to 8.5 inches were reported over northern Florida in association with Josephine.

c. Casualty and Damage Statistics

Total insured losses from Josephine in Florida, Georgia, South Carolina, North Carolina, and Virginia are estimated to be $65 million. This gives a rough estimate of $130 million for the total storm damage. There were no deaths that could be directly attributed to Josephine. A woman suffered a heart attack during a tornado in Edgewater, and a surfer suffered a broken leg in Pinellas County.

d. Forecast and Warning Critique

There were some large track forecast errors for Josephine; the number of cases was rather small, however. The average 12-, 24-, 36-, 48-, and 72-hr official forecast errors were 70, 131, 203, 266, and 401 n mi respectively. These are 41% to 49% larger than the most recent 10-year average track errors. The sample size was only 8 cases for 12 through 48 hours, and 7 cases for 72 hours. The intensity forecasts were generally off by 10 knots or less for all time periods.

Table 4 lists the various watches and warnings that were issued for Josephine. There was about 19 hours between the issuance of the tropical storm warning and landfall in Taylor County.

Table 1. Best track, Tropical Storm Josephine, 4-8 October, 1996

Date/Time (UTC)	Position		Pressure (mb)	Wind Speed (kt)	Stage
	Lat. (°N)	Lon. (°W)			
4/1800	22.7	96.2	1003	25	tropical depression
5/0000	23.0	96.1	1003	30	"
0600	23.3	96.0	1003	30	"
1200	23.6	95.8	1003	30	"
1800	24.3	95.5	1003	30	"
6/0000	24.8	95.0	1002	30	"
0600	25.0	94.5	1002	30	"
1200	25.1	93.5	1003	30	"
1800	25.1	91.8	1001	35	tropical storm
7/0000	25.5	90.4	996	40	"
0600	25.9	88.9	992	50	"
1200	26.9	87.3	981	60	"
1800	28.2	86.0	983	60	"
8/0000	29.3	84.5	983	60	"
0600	30.9	82.3	990	45	extratropical
1200	34.0	79.0	988	45	"
1800	36.0	76.0	986	45	"
9/0000	38.0	73.5	983	45	"
0600	41.0	71.0	980	45	"
1200	42.5	68.0	980	45	"
1800	44.5	65.5	984	45	"
10/0000	46.5	62.5	985	45	"
0600	48.5	58.0	985	45	"
1200	49.5	55.0	983	45	"
1800	50.5	50.0	984	45	"
11/0000	51.0	44.0	984	45	"
0600	51.0	38.0	986	45	"
1200	51.0	32.0	988	45	"
1800	51.0	26.0	989	45	"
12/0000	51.0	21.0	985	45	"
0600	51.0	18.0	980	45	"
1200	51.5	16.5	982	45	"
1800	52.5	15.5	977	50	"
13/0000	53.0	15.5	973	55	"
0600	53.5	15.5	971	60	"
1200	54.0	15.5	972	55	"
1800	55.5	15.5	977	50	"

Table 1 (continued). Best track, Tropical Storm Josephine, 4-8 October, 1996

14/0000	57.5	16.0	982	45	"
0600	60.0	18.0	977	45	"
1200	61.0	20.0	972	45	"
1800	62.0	22.0	970	45	"
15/0000	62.5	24.0	972	45	"
0600	63.0	26.0	978	45	"
1200	63.0	28.0	983	40	"
1800	63.0	29.5	988	35	"
16/0000	63.0	30.5	992	30	"
0600					merged with larger low

7/1200	26.9	87.3	981	60	minimum pressure (as a tropical system)
8/0330	30.0	83.9	983	60	landfall in Taylor County, midway between Dekle Beach and St. Marks, Fla.

Table 2. Ship reports of 34 knots or higher wind speed associated with Tropical Storm Josephine, October, 1996.

date/time (UTC)	ship call sign	latitude (°N)	longitude (°W)	wind dir/ speed(knots)	pressure (mb)
06/1800	ELPG9	25.1	90.1	190/35	1000.5
06/2100	ELPG9	24.5	90.5	220/41	995.8
07/0900	KCZC	27.4	89.7	050/40	1000.0
07/0900	9VBK	28.7	89.6	030/41	1004.0
07/1200	KCZC	27.5	89.7	030/40	1000.5
07/1200	9VBK	28.8	89.4	050/38	1003.5
07/1500	C6JN	29.4	87.7	050/48	1001.8
07/1500	KCZC	27.7	89.6	030/40	1002.0
07/1500	9VBK	29.0	89.0	040/50	1003.5
07/1800	C6JN	29.3	87.7	040/58	998.6
07/1800	ELFT8	23.5	84.3	220/34	1010.5
07/1800	ELRV2	22.8	87.3	230/35	1000.1
07/1800	KCZC	27.7	89.5	030/40	1003.0
07/1800	WCHF	28.1	88.6	020/44	1008.8
07/1800	WGXN	24.7	85.2	190/45	994.1
07/1800	WLBV	24.5	85.6	210/44	999.2
07/1800	3EKI3	21.9	85.1	200/35	1003.5
07/1800	9VBK	29.4	88.9	020/55	1003.0
07/2100	C6JN	29.2	87.7	030/49	998.8
07/2100	KCZC	27.8	89.4	020/40	1003.0
07/2100	9VBK	29.7	89.4	010/35	1004.7
08/0000	C6JN	29.2	87.7	020/47	999.9
08/0000	ELFT8	22.3	85.2	200/34	1010.4
08/0000	KCZC	27.8	89.4	030/35	1003.5
08/0000	KGDF	27.1	90.3	340/35	1004.0
08/0300	C6JN	29.2	87.7	010/38	1003.0
08/0300	KCZC	27.9	89.3	030/35	1006.3
08/0300	WCHF	26.0	85.8	300/38	999.5

Table 3. Tropical Storm Josephine selected surface observations, October, 1996.

Location	Press. (mb)	Date/ time (UTC)	Sustained wind (kts)[a]	Peak gust (kts)	Date /time (UTC)[b]	Storm surge (ft)[c]	Storm tide (ft)[d]	total rain (in)
Florida								
Arcadia/Horse Ck								5.66
Brooksville	995.9	08/0037	21	36	07/1917			1.58
Cedar Key	992.6	08/0000	35	43	08/0200			
Clearwater tide gauge			36	51	08/0100			
Dekle Beach							6.0	
Foley (Taylor County)								8.50
Fort Myers	999.7	08/1007	37	47	08/0947			1.92
Horseshoe Beach				44	08/0223			
Inverness								2.93
Jacksonville Airport	992.2	08/0256		41	08/0654			6.15
Jacksonville Naval Air Stn.				36	08/0650			5.88
Jacksonville Cecil Field	993.2	08/0337		42	08/0124			5.86
Keaton Beach	991.9	08/0100		29*	08/0000			
Lake Iamonia (Leon County)								5.73
Lakeland	999.3	07/2351	20	28	07/2351			1.51
Macdill AFB	997.3	07/2355	30	48	08/0410			3.51
Madison								5.10
Mayport Naval Station	993.2	08/0555		39	08/0758			4.19
Melbourne	999.0	08/0750	15	34	08/0715			1.57
Mill Creek (Madison County)								6.14
Monticello								4.50
New Port Richey	996.3	08/0023	26	37	08/0005			2.53
Old Port Tampa			35	56	08/0524			
Orlando (MCO)	997.3	08/0804	26	34	08/0323			0.78
Perry								5.07
Punta Gorda	999.3	08/0954	36	49	08/1016			1.42
Ruskin								2.59
Secatan (Taylor County)								7.90
St. Petersburg	996.6	07/2355	29	39	08/0051			2.90
St. Pete pier			28	38	08/0054			
St. Petersburg uncom. ASOS	995.9	08/0014	36	42	08/0344			
Sarasota/Bradenton Airport	998.3	07/2250	27	40	08/0150			2.57
Steinhatchee							6.9	
Sunshine Skyway	993.0	08/0154	39	62	07/2345			
Suwannee							9.3	
Tallahassee	993.5	08/0229	25	34	08/0229			7.79
Tampa Airport	996.6	08/0029	23	46	08/0257			
Tampa Palms (Ira Brenner)								5.53
Venice	1000.2	07/2300	33	43	08/0000			
Winter Haven	998.3	08/1026	27	35	08/0627			2.76

[a]NWS standard averaging period is 1 min; ASOS and C-MAN are 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.
*May not have been peak value

Table 4. Watch and warning summary, Tropical Storm Josephine, October 1996.

Date/time (UTC)	Action	Location
7/0300	tropical storm watch issued	Apalachicola to Venice, Florida
7/0900	tropical storm warning issued	Apalachicola to Venice, Florida
7/1200	hurricane warning issued	Apalachicola to Anclote Keys, Florida
7/1200	tropical storm warning issued	west of Apalachicola to Fort Walton Beach, Florida
7/1500	tropical storm warning issued	Cape Canaveral, Florida to Little River Inlet, South Carolina
8/0300	hurricane warning downgraded to tropical storm warning	Apalachicola to Anclote Keys, Florida
8/0300	tropical storm warning discontinued	west of Apalachicola to Fort Walton Beach, Florida
8/0900	tropical storm warning changed to gale warning	Cape Canaveral, Florida to Little River Inlet, South Carolina
8/0900	tropical storm warning discontinued	Apalachicola to Venice, Florida

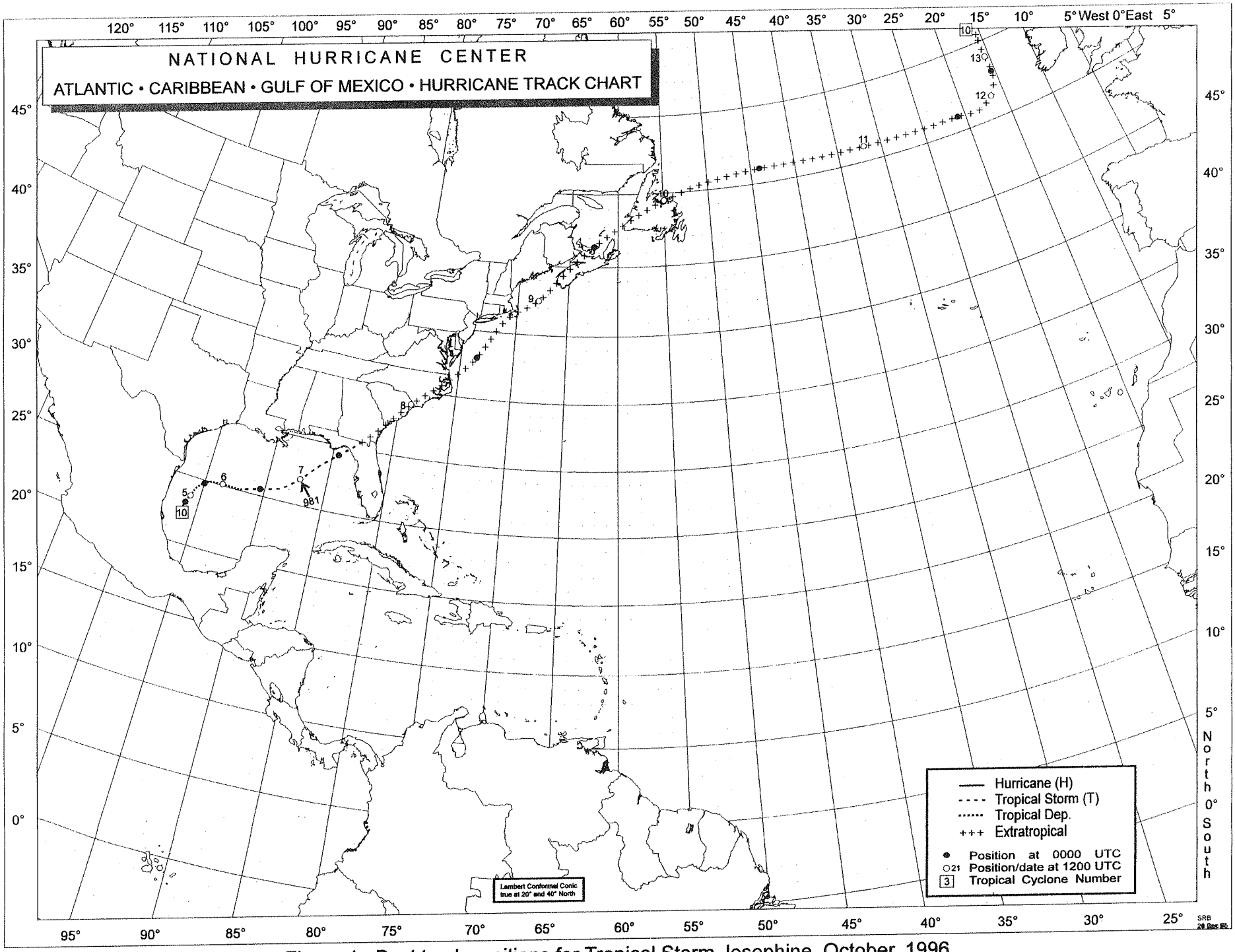

Figure 1. Best track positions for Tropical Storm Josephine, October, 1996

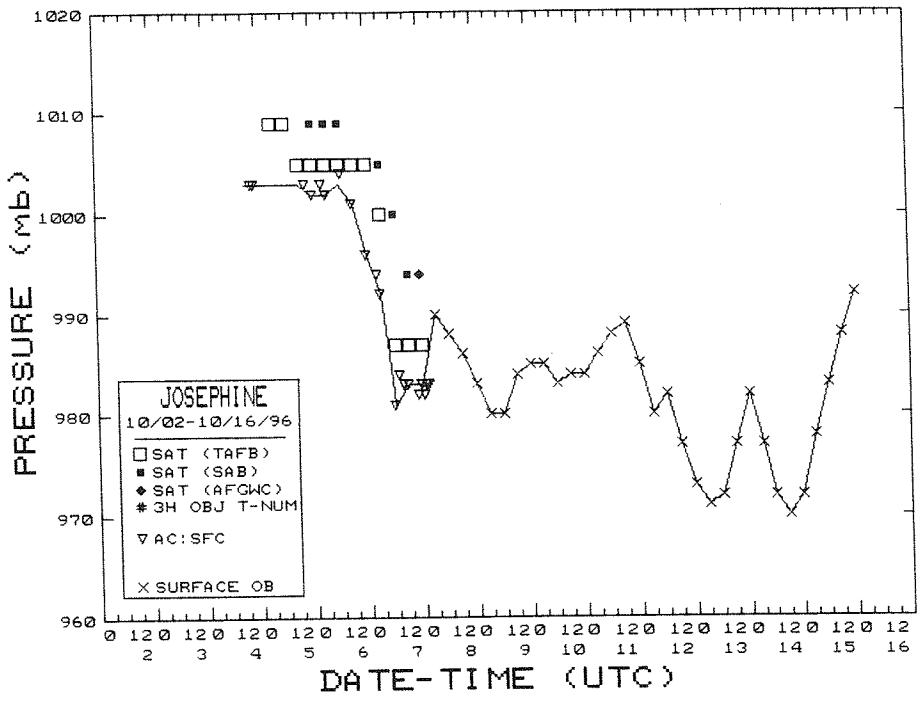

Figure 2. Best track minimum central pressure curve for Tropical Storm Josephine, October, 1996.

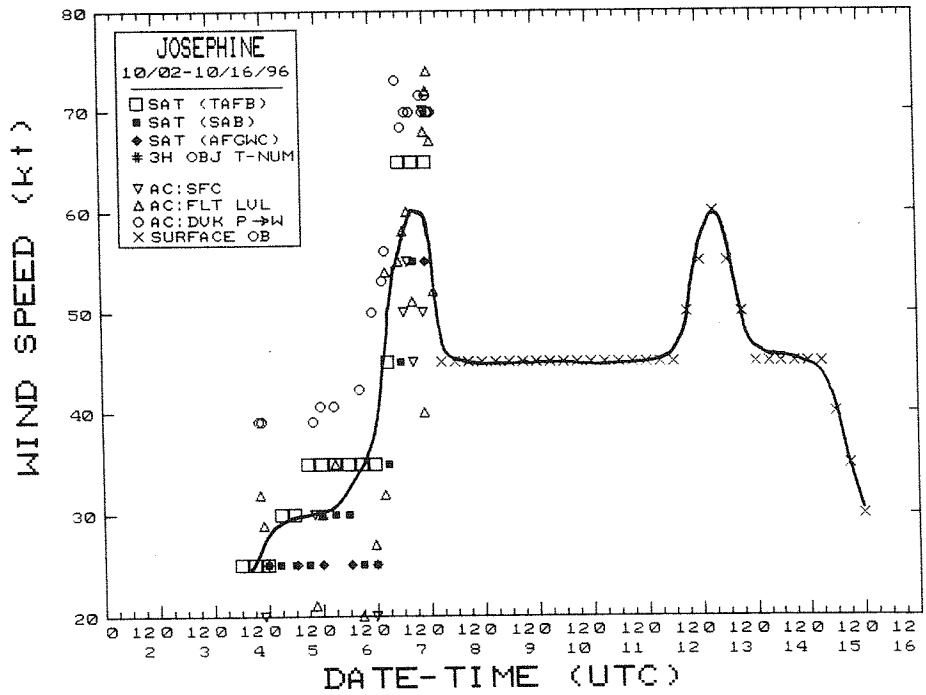

Figure 3. Best track maximum one-minute wind speed curve for Tropical Storm Josephine, October, 1996.