

Tropical Cyclone Report  
Hurricane Michelle  
29 October - 5 November 2001

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Michelle was a late-season Category 4 hurricane. It was the strongest hurricane to hit Cuba since 1952, and it left a trail of death and destruction from Central America to the Bahamas.

a. Synoptic history

The origin of Michelle was a tropical wave that moved westward across the coast of Africa on 16 October. The wave showed few signs of development while it crossed the Atlantic to the Lesser Antilles by 23 October. Associated shower activity increased on 26 October when the wave reached the western Caribbean, and a broad low pressure area formed near the coast of Nicaragua the next day. A gradual increase in organization followed, and an Air Force Reserve Hurricane Hunter aircraft found that the system had become a tropical depression near 1800 UTC 29 October over the coast of Nicaragua, between Puerto Cabezas and Bluefields (Table 1 and Figure 1).

The depression meandered over eastern Nicaragua for the next 36 hours. A slow north-northeastward motion that began early on the 31<sup>st</sup> brought the center back over the Caribbean waters later that day near Cabo Gracias a Dios on the border between Honduras and Nicaragua. The system became Tropical Storm Michelle near 0000 UTC 1 November about 50 n mi north of Cabo Gracias. Michelle moved slowly north-northwestward on the 1<sup>st</sup> and steadily strengthened. It became a hurricane on the 2<sup>nd</sup> while it drifted slowly northward. Rapid intensification then occurred, with maximum sustained winds increasing from 70 kt at 1200 UTC on the 2<sup>nd</sup> to 115 kt at 1200 UTC on the 3<sup>rd</sup>. The central pressure fell from 988 mb at 0605 UTC on the 2<sup>nd</sup> to 937 mb at 1115 UTC on the 3<sup>rd</sup> -- a decrease of 51 mb in about 29 hours. Satellite imagery near the latter time shows a classically-organized hurricane with a well-defined eye embedded in a central dense overcast surrounded by outer banding (Figure 2).

Michelle turned slowly north-northeastward after 1200 UTC the 3<sup>rd</sup> while some fluctuations in intensity occurred. It reached a peak intensity of 120 kt from 0600-1800 UTC on the 4<sup>th</sup> while accelerating northeastward. This motion brought the center of Michelle to the southwestern offshore islands of Cuba near 1800 UTC that day as a Category 4 hurricane on the Saffir-Simpson hurricane scale, and to the Cuban mainland near the Bay of Pigs about 5 hours later.

The eye of Michelle was disrupted by the passage over Cuba and increasing mid- to upper-level southwesterly flow. This led to the cyclone gradually losing tropical characteristics on 5 November while it accelerated northeastward through the Bahamas. The center moved off the coast of Cuba near 0600 UTC, passed over Andros Island near 1200 UTC, and over Eleuthera Island near 1800 UTC. Michelle became a vigorous extratropical cyclone around 0000 UTC on the 6<sup>th</sup>, and the center could be followed for another 18 hours before being absorbed into a strong frontal system.

## b. Meteorological statistics

Table 1 shows the “best track” positions and intensities for Michelle, with the track plotted in Figure 1. Figures 3 and 4 depict the curves of minimum central sea-level pressure and maximum sustained one-minute average “surface” (10 m above ground level) winds, respectively, as functions of time. These figures also contain the data on which the curves are based: aircraft reconnaissance and dropsonde data from the Air Force Reserve and NOAA Hurricane Hunters, satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB) of the National Environmental Satellite Data and Information Service (NESDIS), and the Air Force Weather Agency, and estimates from surface synoptic data.

The Air Force Reserve Hurricane Hunters made 40 center “fixes” on Michelle, while the NOAA aircraft made 11 fixes during the time the center was near Cuba. The maximum observed flight-level winds at 700 mb were 135 kt at 0258 UTC 4 November about 18 n mi south-southwest of the center. An eyewall dropsonde near 0408 UTC on the 4<sup>th</sup> reported 160 kt winds at the 841 mb pressure level. The maximum surface wind reported by land stations was 108 kt with a gust to 113 kt at Cayo Largo, Cuba at an unknown time on the 4<sup>th</sup>. A 113 kt gust was also measured at Jagüey Grande, Cuba on the 4<sup>th</sup>. Abaco Island in the Bahamas reported 63 kt sustained winds at 1500 UTC on the 5<sup>th</sup>, while Nassau reported a gust to 89 kt. Unofficial observations relayed by amateur radio from other parts of the Bahamas indicated sustained winds of 70-80 kt. Sustained winds of tropical-storm force were reported from portions of the Florida Keys and southeastern Florida. Bermuda also reported gusts to tropical storm-force winds, but these may have been more related to the frontal system that absorbed Michelle than to the storm itself. Additional selected surface observations are included in Table 2.

The minimum pressure observed by reconnaissance aircraft was 933 mb at 1921 UTC and 2101 UTC 3 November. The latter observation was accompanied by the lowest observed 700 mb height of 2491 m and is thus chosen as the time of the overall minimum pressure in Michelle. The minimum pressure observed by land stations was 949.7 mb at Cayo Largo on the 4<sup>th</sup>. Nassau reported a 983.7 mb pressure at 1500 UTC on the 5<sup>th</sup> as the center passed to the south. Puerto Cabezas, Nicaragua reported a 1004.1 mb pressure at 2100 UTC 30 October as Michelle meandered over eastern Nicaragua.

A notable aspect of Michelle was that the aircraft-reported winds and pressures appeared to be somewhat out of phase. Aircraft-reported winds at the time of the minimum pressure were roughly 10 kt lower than the previous mission six hours earlier during rapid intensification. The winds and pressure then both rose simultaneously over the next 9-12 hours as Michelle reached peak intensity. This relationship could be partly due to sampling issues, as no aircraft were in the storm during the last 6 h of the rapid intensification when Michelle showed its best organization in satellite imagery.

Aircraft 700 mb wind data after Michelle became extratropical on 6<sup>th</sup> indicated winds as high as 106 kt. This would normally support surface winds of 90-95 kt using reduction factors developed for eyewall conditions (Fig. 4). However, no significant convection was associated with the storm at that time. Thus, the best track intensity is set to a more conservative 75 kt using reduction factors

for non-convective situations.

Several ships encountered Michelle, with selected observations of tropical-storm force or greater winds given in Table 3. While most of the encounters were well away from the center, two ships met the core of Michelle. The first was the **Scan Partner**, which reported Beaufort force 8/9 winds (34-47 kt) and a 988 mb pressure at 0730 UTC 2 November. The ship was near the center of Michelle just before the cyclone reached hurricane strength. The second was from a ship with the call sign **ELWU7** (name unknown) which reported 60 kt winds and a 995.0 mb pressure at 1200 UTC 5 November. Additionally, a drifting buoy near Cat Island in the Bahamas reported a 986.7 mb pressure at 1900 UTC on the 5<sup>th</sup>.

The highest reported storm surge is 9-10 ft (3 m) at Cayo Largo which reportedly inundated the entire island. Above normal tides and battering waves 4-5 m high affected other portions of the coasts of western and central Cuba, causing extensive coastal flooding. In the Bahamas, storm surges of 5-8 ft were reported from New Providence Island, while storm surges of unknown magnitude affected Andros, Eleuthera, Cat Island, Exuma, and Abaco. Storm surges of 1-3 ft occurred along portions of the southeastern Florida coast and in the Florida Keys. These surges were part of a prolonged period of strong onshore winds and high tides that produced significant beach erosion along portions of the Florida east coast. Above normal tides and large battering waves also affected the southern and western shores of the Cayman Islands.

The initial slow movement of Michelle and the pre-Michelle disturbance caused widespread heavy rains over portions of Honduras, eastern Nicaragua, northern Costa Rica, and Jamaica. Ten-day storm totals on Jamaica were as high as 37.44 inches at Comfort Castle, and there are numerous other totals of over 15 inches (Table 2a). Additional heavy rains occurred over portions of Cuba, the Bahamas, and the Cayman Islands. Nassau reported 12.64 inches, while Punta del Este on the Island of Youth reported 11.83 inches. Outer rain bands also affected Florida, where rainfall totals were generally 1-3 inches (Table 2).

Two tornadoes were reported in south Florida. An F1 tornado occurred near Belle Glade, while a waterspout moved onshore at Key Biscayne to become an F0 tornado.

### c. Casualty and Damage Statistics

Press reports indicate the death toll from Michelle stands at 17: 6 in Honduras, 5 in Cuba, 4 in Nicaragua, and 2 in Jamaica. The deaths in Honduras, Nicaragua, and Jamaica were due to severe flooding caused by heavy rains. Four of the deaths in Cuba occurred when a building collapsed during the passage of Michelle, while the fifth was a coastal drowning under unknown circumstances. An additional twenty-six people were reported missing in Central America -- 14 in Honduras and 12 in Nicaragua.

Michelle was the strongest hurricane to hit Cuba since Hurricane Fox in October 1952. Preliminary reports from the government of Cuba indicate widespread damage over the central and western parts of the island, with the provinces of Matanzas, Villa Clara, and Cienfuegos the hardest hit. Ten thousand homes were reported destroyed with another 100,000 others damaged. Additional

damage occurred to as yet uncounted businesses and other structures. Severe damage was also reported to the sugar cane crop near the path of the storm. No monetary estimates of the damage are available at this time.

The heavy rains in Honduras and Nicaragua caused widespread flooding with more than 100,000 people forced from their homes. The hardest hit area was the province of Gracias a Dios in the northeastern part of Honduras, where press reports indicate as many as 100 villages were cut off at one time. The northeastern part of Nicaragua was also hit by severe floods in and near Puerto Cabezas. Flooding was also reported in portions of northern Costa Rica, which caused the evacuation of several thousand people. No monetary estimate of damages is available at this time.

The flash flooding and mudslides in Jamaica caused property damage there, although monetary estimates of the amount are not available at this time. The high surf and tides in the Cayman Islands caused about \$28 million in damage in the Cayman Islands, primarily along the west coast of Grand Cayman. The two tornadoes in south Florida were responsible for about \$20,000 in damage.

Additionally, a NOAA P-3 aircraft returned from a mission into Michelle with damage to the tail section, wings, and propellers.

#### d. Forecast and warning critique

Table 4 shows the average track forecast errors during the tropical storm and hurricane stages of Michelle for the official NHC track forecast and a selection of objective guidance models. The NHC average errors were 30 (18 forecasts), 52 (16 forecasts), 75 (14 forecasts), 96 (12 forecasts), and 126 n mi (8 forecasts) for 12, 24, 36, 48, and 72 h, respectively. These values are 30-40% below that of the 10-yr (1991-2000) average from 12-48 h and 40-50 % better than the 10-yr average at 72 h. The errors are also about 20-30% lower than those of Climatology-Persistence (CLIPER) at 12 and 24 h and 30-40 % lower at other times -- indicating considerable skill for this excellent set of forecasts. As good as the official forecasts were, forecasts from the Aviation run of the National Weather Service's Medium Range Forecast Model were even better. None of the average errors of either the model (AVNO) or the interpolated previous model run (AVNI) exceeded 58 n mi at any time - a phenomenal set of forecast errors.

Examination of the individual official forecast tracks reveals that the vast majority correctly forecast the general motion of Michelle -- a slow northward motion followed by a turn to the northeast. The largest source of error came from an overestimate of how far northward Michelle would move before turning northeastward. Some forecast models showed troubling biases during Michelle -- the GFDL showed a consistent northwestward bias, while several of the NOGAPS forecasts moved the storm over the Yucatan Peninsula of Mexico. These problems contributed to relatively poor track forecasts errors for those models.

The official intensity forecast errors were 9, 11, 17, 22, and 20 kt at 12, 24, 36, 48, and 72 h respectively. These are near or somewhat above the 10-yr averages of 7.0, 10.8, 13.7, 16.3, and 19.6 kt for those time periods. The largest intensity forecast errors occurred due to the rapid

intensification of Michelle from moderate tropical storm to Category 4 hurricane. While the possibility of rapid intensification was foreseen in the NHC forecasts and in experimental guidance in the SHIPS model, the amount was underforecast.

Table 5 shows the watches and warnings issued for Michelle. The intensity and relatively predictable motion of Michelle produced long lead times for watches and warnings in Cuba. Hurricane watches were issued 51 hours before the center reached the coastal islands of Cuba, while hurricane warnings were issued 31 hours before the center arrived. In the Bahamas, hurricane watches were issued 33 hours before the center reached Andros Island, while hurricane warnings were issued 21 hours before the center arrived. In the Florida Keys, a tropical storm warning and a hurricane watch were issued about 42-48 hours before the arrival of the worst conditions, while a hurricane warning was issued 18-24 hours before the onset of the worst conditions. Tropical storm warnings were somewhat short-fused in the Cayman Islands, where they were issued about 6-12 hours before the closest approach of the center. This was due mainly to the somewhat earlier than expected northeastward turn. However, a tropical storm watch was issued for Grand Cayman Island about 42 hours before the closest approach of the center.

#### Acknowledgments:

Much of the U. S. data in this report were provided by the local National Weather Service forecast offices in Key West and Miami, FL. C-MAN station data were provided by the National Data Buoy Center. The Meteorological Services of Cuba, the Bahamas, the Cayman Islands, and Jamaica provided the data for those countries.

Table 1. Best track, Hurricane Michelle, 29 October - 5 November 2001

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
29 / 1800	13.3	83.6	1004	30	tropical depression
30 / 0000	13.7	83.6	1004	30	"
30 / 0600	13.7	84.1	1005	30	"
30 / 1200	13.3	83.9	1005	30	"
30 / 1800	13.0	83.5	1006	30	"
31 / 0000	13.7	83.6	1004	30	"
31 / 0600	14.3	83.4	1005	30	"
31 / 1200	14.8	83.2	1004	30	"
31 / 1800	15.3	83.1	1004	30	"
01 / 0000	15.8	83.1	1001	35	tropical storm
01 / 0600	16.5	83.4	999	45	"
01 / 1200	16.8	83.6	995	50	"
01 / 1800	17.0	83.8	993	50	"
02 / 0000	17.3	83.9	991	55	"
02 / 0600	17.5	83.9	988	60	"
02 / 1200	17.8	84.0	979	70	hurricane
02 / 1800	18.0	84.0	969	80	"
03 / 0000	18.5	84.0	957	90	"
03 / 0600	18.8	84.3	942	105	"
03 / 1200	18.9	84.3	937	115	"
03 / 1800	19.3	84.1	934	110	"
04 / 0000	19.7	83.7	938	115	"
04 / 0600	20.1	83.3	944	120	"
04 / 1200	20.8	82.5	947	120	"
04 / 1800	21.5	81.8	949	120	"
05 / 0000	22.3	80.9	953	105	"
05 / 0600	23.1	79.7	972	80	"
05 / 1200	24.3	78.0	974	80	"
05 / 1800	25.4	76.4	980	75	"
06 / 0000	26.3	74.5	980	75	extratropical

Table 1. Best track, Hurricane Michelle, 29 October - 5 November 2001

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
06 / 0600	26.9	72.6	980	75	"
06 / 1200	27.3	69.7	984	65	"
06 / 1800	28.7	66.5	989	55	"
07 / 0000					absorbed by frontal system
03 / 2100	19.4	83.9	933	110	minimum pressure
Landfalls:					
04/ 1800	21.5	81.8	949	120	Cayo Largo, Cuba
04/ 2300	22.1	81.2	950	115	Bay of Pigs, Cuba
05/ 1200	24.3	78.0	973	80	Andros Island, Bahamas
05/ 1800	25.4	76.4	980	75	Eleuthera Island, Bahamas

Table 2.  
Hurricane Michelle selected surface observations, 29 October - 5 November 2001.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)			
<b>Bahamas</b>								
Abaco			05/1500	63				
Eleuthera			05/1500	59				
Freeport (MYGF)			05/1300	40	52			
Georgetown			05/1350	39	51			
Lee Stocking Island (NOAA CREWS) <sup>f</sup>	05/1600	989.8	05/1600	45	54			
Marsh Harbor	05/1800	995.6			72			
Nassau (MYNN)	05/1500	983.7	05/1800	48	89			12.64
New Providence						5-8		
<b>Cayman Islands</b>								
Cayman Brac			04/????		35			
Grand Cayman	04/0900	1001.3	04/1400	23	38			6.52
<b>Cuba</b>								
Aguada de Pasajeros <sup>f</sup> (78335)	05/0030	958.5	04/2300	65 <sup>e</sup>	95			
Bainoa (78340)	04/2045	996.1	04/2240	49 <sup>e</sup>	76			3.28
Batabano (78322)	04/1900	995.3	04/2310	45 <sup>e</sup>	54			2.53
Bauta (78376)	04/2030	999.1	04/2100	49 <sup>e</sup>	60			1.59
Camilo Cienfuegos	05/0510	987.4	05/0515	46	63			4.13
Casablanca (78325)	04/2110	993.4	04/2115	60 <sup>e</sup>	72			1.75
Cayo Largo (MUCL)	04/????	949.7	04/????	108	113		9-10	
Ciego de Avila (MUCA)			04/????	27	43			
Cienfuegos (78344)	05/0100	958.9	04/2300	65 <sup>e</sup>	91			
Colón (78332)	04/2300	980.9	04/1900	38 <sup>e</sup>	79			3.39
Cuba-Francia (78309)	04/1656	991.7	04/1332	54 <sup>e</sup>	71			4.09 <sup>g</sup>
Güines (78323)	04/2030	993.4	05/0125	44 <sup>e</sup>	64			0.93
Güira de Melena (78320)	04/2055	997.7	05/0050	32 <sup>e</sup>	56			3.09
Havana (MUHA)			05/0150	36	58			
Jagüey Grande (78331)	05/0000	992.8	04/2100	84	113			9.22
Jíbaro (78341)	05/0400	995.5	05/0415	37 <sup>e</sup>	58			3.39
Jovellanos (78330)	05/0000	985.3	04/2300	37 <sup>e</sup>	54			6.49
La Fe (78321)	04/1500	991.6	04/1900	54 <sup>e</sup>	60			4.68 <sup>g</sup>
Melena del Sur (78375)	04/2100	994.8	04/2253	43 <sup>e</sup>	73			2.39
Nueva Gerona (78221)	04/1730	994.3	04/1630	50 <sup>e</sup>	65			
Playa Girón (78333)	04/2300	960.5	04/1900	62	105			5.10
Punta del Este (78324)	04/1700	981.4	04/1645	69 <sup>e</sup>	86			11.83



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)			
Sagua La Grande (78338)	05/0410	977.0	05/0220	49 <sup>e</sup>	81			2.24
Sancti Spiritus (78349)	05/0600	990.1	05/0430	49 <sup>e</sup>	65			2.97
Santiago Las Vegas (78373)	04/2040	997.8	04/2055	49 <sup>e</sup>	74			2.27
Santo Domingo (78326)	05/0300	962.8	05/0500	64 <sup>e</sup>	85			2.41
Tapaste (78374)	04/2050	995.5	04/2100	38 <sup>e</sup>	65			3.84
Topes de Collantes (78342)			05/0505	54 <sup>e</sup>	65			7.60
Trinidad (78337)	05/0400	991.3	05/0435	38 <sup>e</sup>	64			4.78
Unión de Reyes (78327)	05/0000	986.6	05/0030	46 <sup>e</sup>	81			4.57
Varadero (78328)			05/0000	46 <sup>e</sup>	81			3.98
Venezuela (78346)	05/0650	993.0	04/1632	30	52			1.81
Yabú (78343)	05/0455	963.7	05/0300	60 <sup>e</sup>	73			1.83
<b>Nicaragua</b>								
Puerto Cabezas	30/2100	1004.1						
<b>United States/Florida</b>								
Devils Garden								1.59
Dry Tortugas SP								2.40
Ft. Lauderdale (KFLL)	05/1200	1004.2	05/1453	29	41			1.27
Hialeah								1.51
Key Biscayne								1.87
Key West (KEYW)	05/0701	1002.3	05/0438	32	41	1.8		2.56
Marathon (KMTH)	05/0953	1001.2	05/0153	28	37	1.4		1.79
Miami (KMIA)	05/0956	1003.3	05/1529	17	32			1.21
Miami Beach	05/1105	1001.2	05/0805	37	44			1.10
Miami WFO								1.59
NW Florida Bay COMPS	05/0930	1000.7	05/0900	32	41			
Perrine								1.80
Pompano Beach (KPMP)	05/1100	1004.0	05/1300	24	35			1.18
Tamiami (KTMB)	05/1000	1003.0	05/1300	17	26			1.37
Tavernier								2.73
<b>NOAA C-MAN</b>								
Dry Tortugas (DRYF1)	05/0800	1005.4	04/1810	35 <sup>e</sup>	45			
Fowey Rocks (FWYF1)	05/1000	1002.4	05/1410	46 <sup>e</sup>	53			
Lake Worth (LKWF1)	05/1100	1004.3	05/1230	34 <sup>e</sup>	42			
Long Key (LONF1)	05/1000	1000.7	05/1020	35 <sup>e</sup>	43			
Molasses Reef (MLRF1)	05/1200	1000.0	05/0650	41 <sup>e</sup>	50			
Sand Key (SANF1)	05/0600	1001.0	05/0500	42	48			
Settlement Point (SPGF1)	05/2000	1002.8	05/1310	36 <sup>e</sup>	43			

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) <sup>c</sup>	Storm tide (ft) <sup>d</sup>	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) <sup>a</sup>	Sustained (kt) <sup>b</sup>	Gust (kt)			
Sombrero Key (SMKF1)	05/0900	1001.4	05/0730	43 <sup>e</sup>	50			

<sup>a</sup> Date/time is for sustained wind when both sustained and gust are listed.

<sup>b</sup> Except as noted, sustained wind averaging periods for C-MAN and U. S. land-based ASOS reports are 2 min; buoy averaging periods are 8 min. Reports from Cuba are 1 minute averages.

<sup>c</sup> Storm surge is water height above normal astronomical tide level.

<sup>d</sup> Storm tide is water height above National Geodetic Vertical Datum (1929 mean sea level).

<sup>e</sup> 10-minute average

<sup>f</sup> Station disabled by storm - incomplete record

<sup>g</sup> 3 November total

Table 2a. Rainfall data from Jamaica for the period 27 October - 5 November 2001.

<b>Location</b>	<b>Rainfall (inches)</b>	<b>Location</b>	<b>Rainfall (inches)</b>
Agulta-Vale	22.31	Kingston (Norman Manley Airport)	8.20
Bachelor's Hall	14.41	Laughlands	17.63
Boscobel	17.19	Lawrence Tavern	10.06
Bowden	18.00	Mavis Bank	18.61
Brimmer Hall	16.93	Middlesex	20.27
Brown's Town	12.25	Moore Town	31.04
Castleton Garden	26.45	Norbrook	11.03
Cavaliers	9.59	Orange River	20.24
Cedar Valley	21.01	Passely Gardens	15.50
Comfort Castle	37.44	Port Antonio	6.87
Constant Spring	13.01	Port Maria	14.74
Discovery Bay	10.71	Richmond	21.56
Duckenfield	17.78	Rowlandsfield	17.05
Fern Gully	19.43	Runaway Bay	15.42
Hampstead	29.11	Seaview	8.57
Hope	10.67	Spring Garden	24.66
Industry	12.91	Stony Hill	18.70
Irish Town	12.49	Walkerswood	19.78
Jacks Hill	10.02	Waterloo Road	9.35

Table 3. Selected ship and buoy reports from Hurricane Michelle, 29 October-5 November 2001.

Date/Time (UTC)	Ship name/ call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
01/1800	<b>Jo Cedar</b> /PFDI	18.2	81.6	100/37	1007.0
02/0730	<b>Scan Partner</b> /(unknown)	17.5	84.1	See Note	988.0
04/0600	C6FN5	24.0	79.3	070/42	1006.0
04/0900	<b>Star Florida</b> /LAVW4	24.2	81.5	060/37	1007.2
04/1500	<b>Nobel Star</b> /KRPP	24.1	83.6	050/39	1008.0
04/1800	<b>Emmagracht</b> /PDYX	23.6	81.1	080/39	1003.0
04/1800	C6QU3	18.0	81.1	240/34	1004.0
05/1200	ELWU7	25.3	75.9	050/60	995.0
05/1200	<b>Nedlloyd Van Nes</b> /ELVG7	26.7	79.6	050/48	1003.5
05/1900	Drifting Buoy 41651	24.3	75.4	N/A	986.7
06/0200	ELWX5	20.3	68.0	190/38	1006.9
06/0600	<b>Washington Senator</b> /DEAZ	29.7	77.3	020/37	1011.8
06/0600	<b>Liberty Star</b> /WCBP	23.1	72.5	270/40	1003.2

Note: The **Scan Partner** reported winds of Beaufort force 8/9, which is 34-47 kt. No direction was given.

Table 4. Preliminary track forecast evaluation for Hurricane Michelle - heterogeneous sample. Errors in nautical miles for tropical storm and hurricane stages with number of forecasts in parentheses. Numbers in bold represent forecasts which were better than the official forecast.

Forecast Technique	Period (hours)				
	<b>12</b>	<b>24</b>	<b>36</b>	<b>48</b>	<b>72</b>
CLIP	39 (18)	80 (16)	127 (14)	156 (12)	183 (8)
GFDI	42 (17)	94 (15)	153 (13)	197 (11)	237 (7)
GFDL*	49 (18)	90 (16)	151 (14)	195 (12)	230 (8)
LBAR	39 (18)	100 (16)	165 (14)	230 (12)	315 (8)
VBRI*	45 (16)	100 (14)	160 (12)	227 (10)	294 (6)
VBAR	35 (12)	88 (11)	150 (9)	217 (8)	310 (5)
AVNI	35 (17)	<b>44</b> (15)	<b>58</b> (13)	<b>55</b> (11)	<b>50</b> (7)
AVNO*	45 (16)	<b>46</b> (14)	<b>50</b> (12)	<b>52</b> (11)	<b>48</b> (8)
BAMD	46 (18)	83 (16)	105 (14)	111 (12)	163 (8)
BAMM	43 (18)	77 (16)	82 (14)	<b>76</b> (12)	<b>95</b> (8)
BAMS	81 (18)	155 (16)	172 (14)	180 (12)	220 (8)
NGPI	51 (18)	106 (16)	174 (14)	236 (12)	397 (8)
NGPS*	42 (9)	86 (8)	143 (7)	205 (6)	312 (4)
UKMI	40 (15)	80 (13)	116 (11)	154 (10)	225 (7)
UKM*	43 (9)	64 (8)	102 (7)	131 (6)	182 (4)
A98E	36 (18)	67 (16)	<b>69</b> (14)	<b>87</b> (12)	172 (8)
A9UK	37 (9)	72 (8)	94 (7)	99 (6)	176 (4)
GUNS	38 (15)	77 (13)	120 (11)	165 (10)	253 (7)
GUNA	32 (15)	59 (13)	93 (11)	132 (10)	196 (7)
NHC Official	30 (18)	52 (16)	75 (14)	96 (12)	126 (8)
NHC Official 10-Year Average (1991-2000)	44 (2049)	82 (1835)	118 (1646)	151 (1475)	225 (1187)

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

Table 5. Watch and warning summary, Hurricane Michelle, 29 October - 5 November 2001.

Date/time (UTC)	Action	Location
01/2100	Hurricane watch issued	Western Cuba including the provinces of Pinar Del Rio, La Habana, Havana City, Matanzas, and the Isle of Youth
02/1700	Tropical storm watch issued	Grand Cayman Island
02/2100	Hurricane watch issued	Cuba including the provinces of Villa Clara, Cienfuegos, Sancti Spiritus, and Ciego de Avila
03/0900	Tropical storm warning and hurricane watch issued	Florida Keys from Ocean Reef to the Dry Tortugas including Florida Bay
03/1100	Hurricane watch upgraded to hurricane warning	Western and Central Cuba including provinces from Pinar Del Rio to Ciego de Avila and the Isle of Youth
04/0300	Hurricane watch issued	Northwestern and Central Bahamas including Grand Bahama, the Abacos, the Berry Islands, Bimini, Andros, New Providence, Eleuthera, Cat Island, Exumas, San Salvador, Rum Cay, and Long Island
04/0300	Tropical storm warning issued	Florida east coast from Jupiter Inlet to Ocean Reef and Florida west coast south of Bonita Beach
04/0600	Tropical storm warning issued	Cayman Islands
04/0900	Hurricane warning issued	Florida Keys from Ocean Reef to the Dry Tortugas including Florida Bay
04/1500	Hurricane watch upgraded to hurricane warning	Northwestern and Central Bahamas including Grand Bahama, the Abacos, the Berry Islands, Bimini, Andros, New Providence, Eleuthera, Cat Island, Exumas, San Salvador, Rum Cay, and Long Island
05/0000	Hurricane watch issued	Bermuda
05/0000	Tropical storm warning discontinued	Cayman Islands
05/0600	Hurricane warning downgraded to tropical storm warning	Florida Keys from Ocean Reef to the Dry Tortugas including Florida Bay

Date/time (UTC)	Action	Location
05/0600	Tropical storm warning discontinued	Florida west coast south of Bonita Beach
05/0900	Gale warning issued	Florida east coast from Cocoa Beach to Jupiter Inlet
05/1200	All warnings discontinued	Cuba
05/1200	Tropical storm warning discontinued	Florida Keys from Craig Key to the Dry Tortugas including Florida Bay
05/1800	Tropical storm warning discontinued	Florida east coast from Jupiter Inlet to Craig Key
05/2100	Hurricane watch changed to tropical storm warning	Bermuda
05/2100	Gale warning discontinued	Florida east coast from Cocoa Beach to Jupiter Inlet
05/2200	Hurricane warning changed to tropical storm warning	Abaco and Eleuthera Islands in the Bahamas
05/2200	Hurricane warning discontinued	Remainder of the Bahamas
06/0300	Tropical storm warning discontinued	Abaco and Eleuthera Islands in the Bahamas
06/2100	Tropical storm warning discontinued	Bermuda

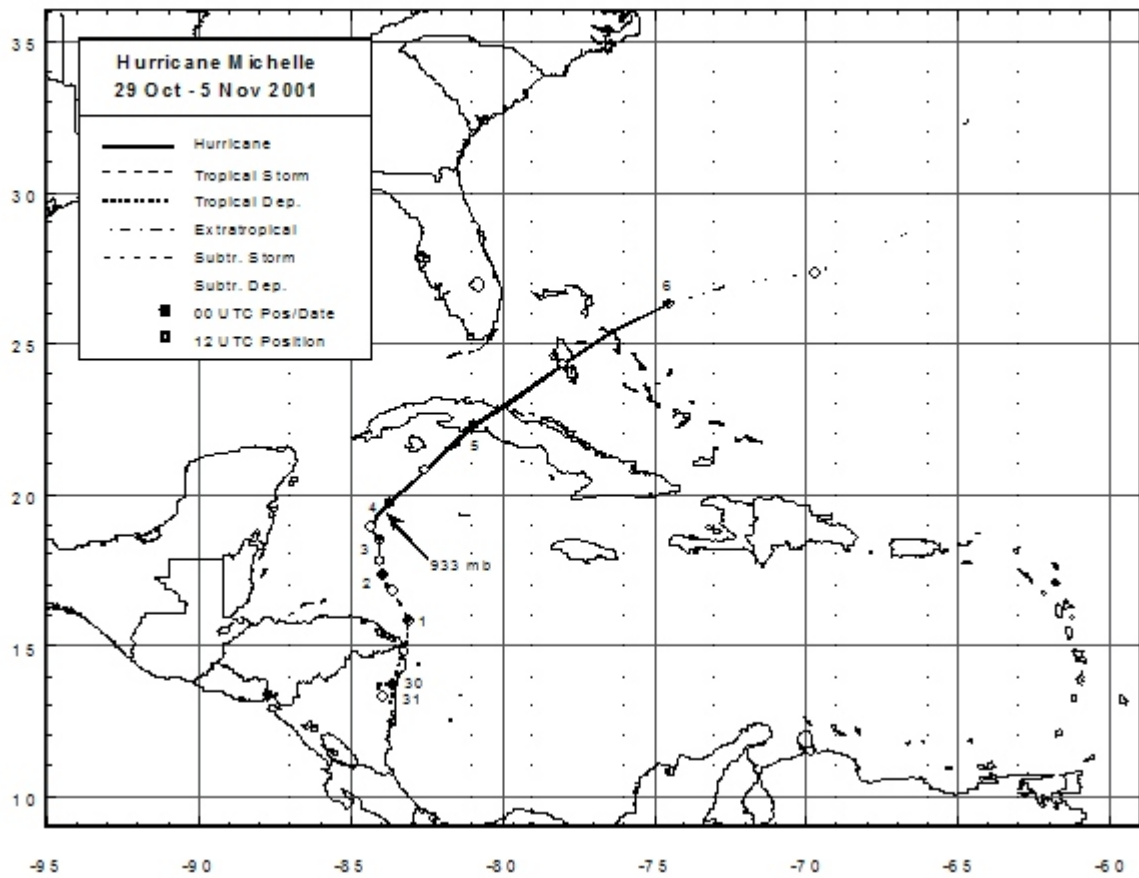


Figure 1. Best track of Hurricane Michelle, 29 October - 5 November 2001



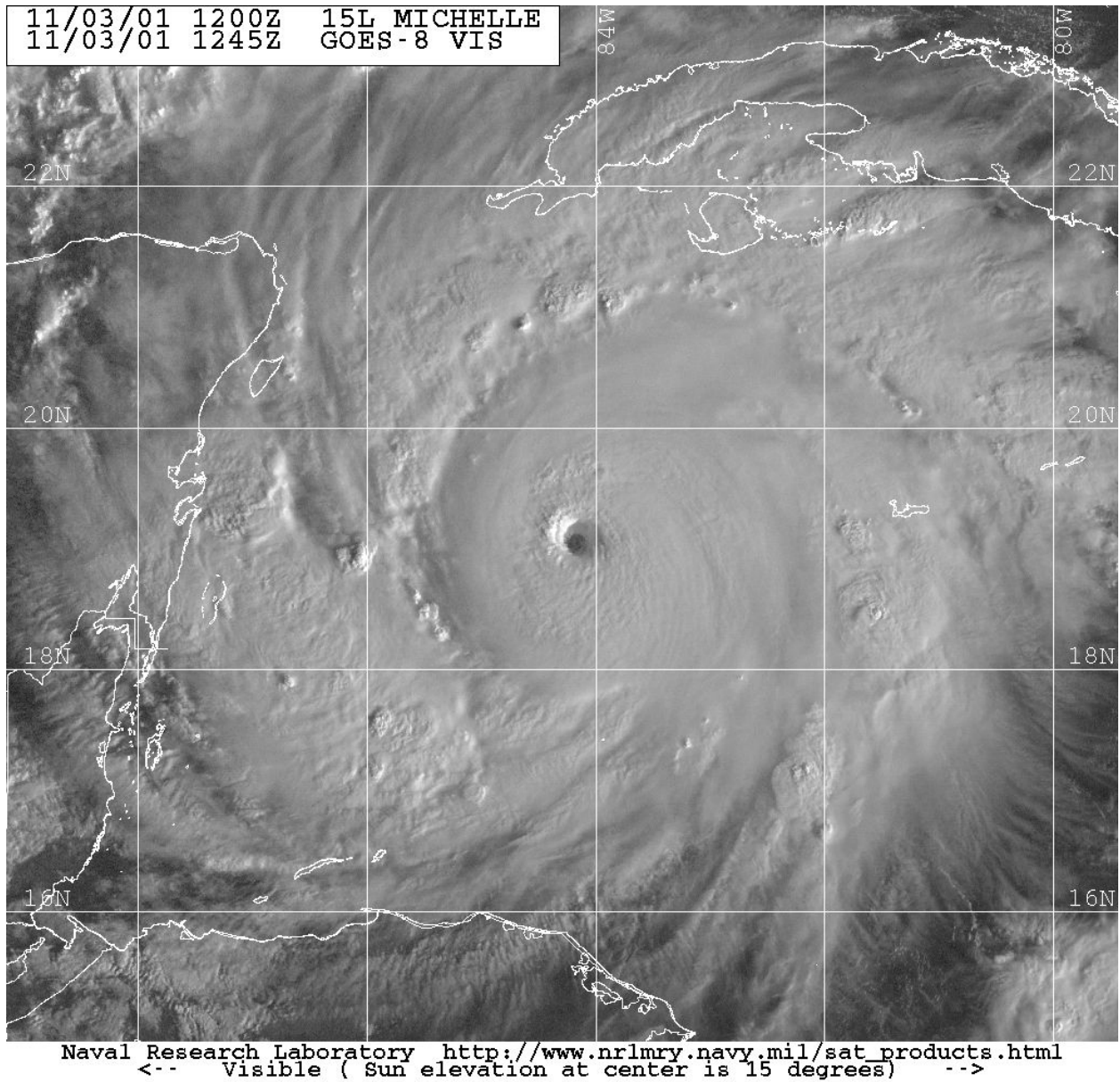


Figure 2. GOES-8 visible image of Hurricane Michelle at 1245 UTC 3 November. Image courtesy of the Naval Research Laboratory, Monterey, CA.

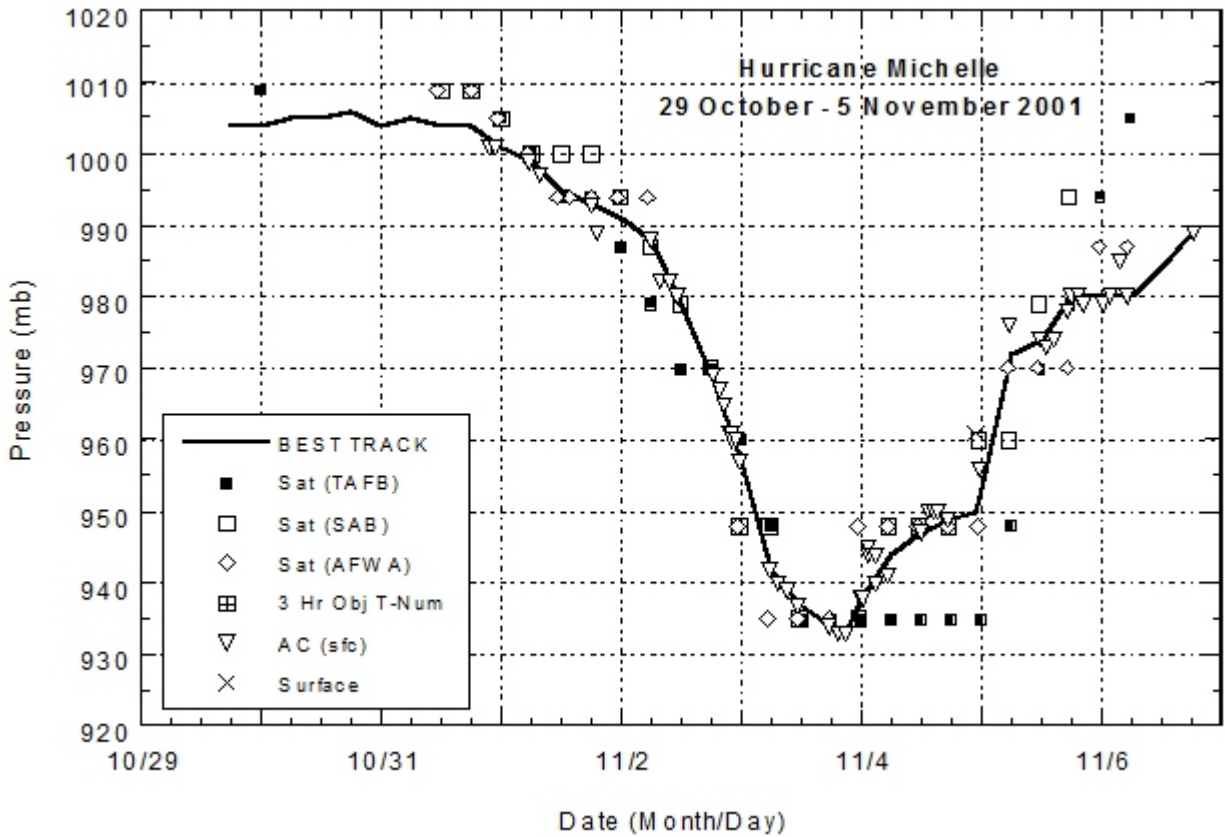


Figure 3. Best track minimum central pressure curve for Hurricane Michelle, 29 October - 5 November 2001.

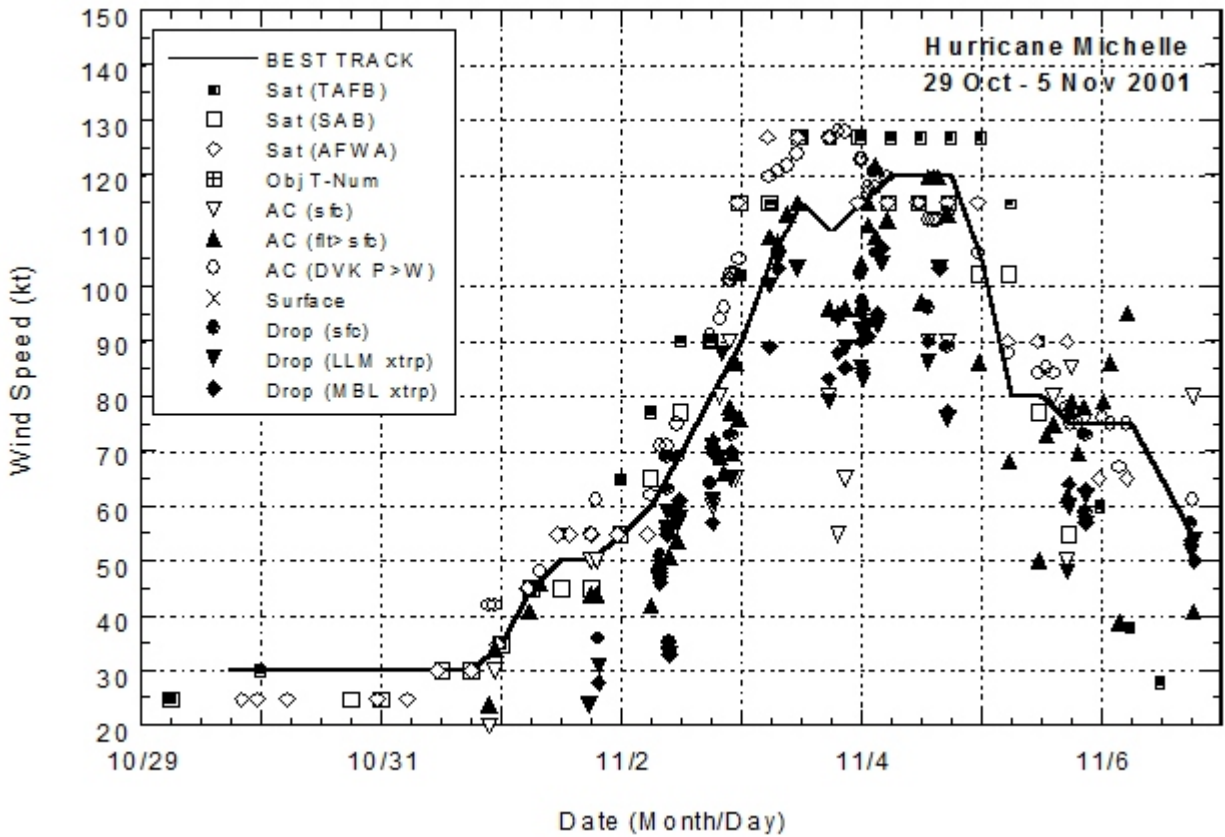


Figure 4. Best track maximum sustained surface wind speed curve for Hurricane Michelle, 29 October - 5 November, 2001, and the observations on which the best track curve is based. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% reduction factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM), and from the sounding boundary layer mean (MBL).

