

Tropical Cyclone Report
Hurricane Michael
17-19 October 2000

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Michael was a short-lived category two hurricane on the Saffir-Simpson Hurricane Scale that developed from subtropical origins off the northeast coast of Florida. Michael moved northeastward over the western and northern Atlantic as a tropical cyclone and eventually crossed Newfoundland as a strong extratropical low pressure system.

a. Synoptic History

The precursor low pressure system to Hurricane Michael developed from the interaction of an upper-level cold low that migrated southward from the mid-latitudes and a stationary front over the southeast Bahama Islands. A cold front pushed off the U.S. southeast coast on 7 October and moved slowly southeast for the next couple of days before it became stationary from Bermuda to central Cuba on 10 October. High amplitude mid-latitude flow in the upper troposphere allowed a cold low to drop southward just off the Florida east coast, which induced the formation of a surface low along the southern end of the front east of the central Bahamas on 12 October. The pressure gradient between the developing surface low and high pressure over the eastern United States created an area of gale force winds several hundred miles northwest of the low center. The surface low remained nearly stationary for more than 24 hours before drifting slowly north-northeastward late on the 13th. On 14 October, the low deepened from 1010 mb to 1003 mb and moved northward to a position about 800 n mi east of Cape Canaveral, FL. After remaining nearly stationary again for almost 24 h, the surface low turned westward and moved underneath the upper level cold low on 15 October. It then stalled again about 650 n mi east of Jacksonville, FL, as a subtropical depression. Later that day, satellite classifications using the Hebert-Poteat technique indicated the low pressure system had strengthened into a subtropical storm. After remaining nearly stationary for an additional 48 h over very warm sea-surface temperatures ($\geq 28^{\circ}\text{C}$), thunderstorms developed and persisted near the low-level center. This allowed the system to gradually acquire tropical characteristics.

Prior to tropical cyclone development, Dvorak satellite intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB), and the Air Force Weather Agency (AFWA) indicated subtropical cyclone classifications as high as ST 2.5 or 35 kt (from the TAFB). However, by 0000 UTC, 17 October, satellite classifications suggested the low pressure system had acquired enough tropical characteristics to become Tropical Storm Michael. The transition from a subtropical to a tropical system was supported by an earlier Advanced Microwave Sounder Unit (AMSU) satellite overpass, which indicated a weak warm core aloft and an upper level outflow. Two QuikSCAT overpasses on the 16th also showed the radius of maximum winds had contracted from 150 n mi to less than 60 n mi between 1029 UTC and 2252 UTC.

Later that day, U. S. Air Force Reserve (USAFR) reconnaissance aircraft indicated that

Michael had strengthened based on 1500 ft flight-level wind reports of 60 kt and 990 mb surface pressure at 1717 UTC, and 72 kt and 988 mb pressure at 1906 UTC. Those values correspond to surface wind speed estimates of around 51 kt and 61 kt, respectively, using a standard reduction of 0.85 for that altitude. Also, experienced hurricane hunter personnel estimated surface winds of 70 kt. Based on the reconnaissance data, it is estimated that Michael became a hurricane at 1800 UTC, 17 October. By 0615 UTC, 18 October, a 20 n mi circular closed eye at 850 mb was noted, along with a minimum surface pressure of 984 mb and flight-level winds of 73 kt. There were slight fluctuations in the flight-level winds and surface pressures for the next 36 hours until rapid deepening occurred on the 19th. As Michael began to interact with the approaching strong mid-tropospheric trough, baroclinic effects may have played a role in Michael's 21 mb pressure drop from 986 mb at 1200 UTC to 965 mb at 1800 UTC. During the rapid deepening phase, the maximum flight-level (1500 ft) wind and minimum pressure observed by reconnaissance aircraft was 95 kt at 1829 UTC, from the NOAA Aircraft Operations Center (NAOC), and 979 mb from the USFAR, respectively, on 18 October.

Reconnaissance flights into Michael ceased after 1957 UTC on 19 October, and subsequent surface pressure and wind reports were obtained from ships, buoys, and land stations. While Michael was a tropical cyclone, the lowest pressure and maximum surface wind observed were 965.5 mb and 80 kt, respectively, which came from ship 3EHR6 (*MSC Xingang*) near the eastern eyewall at 1700 UTC, 19 October. By 2100 UTC, 19 October, extratropical transition began as a sharp shortwave trough embedded in strong southwesterly mid-level flow accelerated Michael northeastward along a surface cold front. Surface data reports indicate merger with the front occurred about 100 n mi southwest of Harbour Breton, Newfoundland. The increasing vertical shear also likely added the extratropical transition.

During landfall along the south coast of Newfoundland as an extratropical system, maximum sustained winds of 69 kt with gusts to 93 kt and a minimum pressure of 967.7 mb were reported near Sagona Island. A few hours prior to landfall, a Canadian reconnaissance aircraft observed an unofficial wind speed of 136 kt at the top of the boundary layer. However, the cool (4° to 10° C) and very stable boundary layer likely prevented those strong winds from mixing down to the surface. Radar imagery (Fig. 4) at 2145 UTC, 19 October, from Holyrood, Newfoundland, indicated a well-defined eye at 1.5 km AGL. However, surface observations and visible satellite imagery indicated that the position of the radar eye was located about 75 n mi northeast of the surface position. Decoupling of the middle and upper level circulation from the low level center further suggests that Michael was rapidly becoming extratropical. Landfall was approximately 2300 UTC, 19 October, about midway between Harbour Breton and Burgeo along the south coast of Newfoundland.

b. Meteorological Statistics

Observations in Michael (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from TAFB, SAB, and AFWA. In addition, flight-level observations are available from flights by the USAFR 53rd Weather Reconnaissance Squadron and the NAOC.

Tables 2 and 2a contain all ship and buoy reports, respectively, of tropical storm force winds (≥ 34 kt) associated with Hurricane Michael. During and after landfall as an extratropical low

pressure system, the Environment Canada weather service reported surface winds in excess of 50 kt (mainly along and east of the storm track) and pressures below 975 mb over nearly all of Newfoundland between 2100 UTC, 19 October, and 0600 UTC, 20 October. However, the Environment Canada weather service did not consider it particularly unusual since "...those communities are no strangers to such winds."

c. Forecast and Warning Critique

The average official track errors for Michael (number of cases in parentheses) were 63 (11), 133 (11), 202 (8), 247 (7), and 299 (4) n mi for the 12, 24, 36, 48 and 72 h forecasts, respectively. These errors are greater than the average official track errors for the 10-yr period 1990-1999 (46, 85, 122, 158, and 235 n mi, respectively) at all times. All available forecast guidance was much better than the official forecasts except for the CLIPER (CLImatological and PERsistence) model, which indicates the official forecasts had some skill. The primary reason for the large errors were due to forecasting a slower and more northward track, which was behind and to the left of the majority of the forecast models. Part of the left-bias in the forecasts was an expected quick transition to and merger with a large-scale extratropical low pressure system. Merger with the extratropical low took about 24 h longer to occur than was originally forecast.

Average official intensity errors for Michael were 11, 14, 21, 25, and 25 kt for the 12, 24, 36, 48, and 72 h forecasts, respectively. Like the track errors, the intensity errors are greater than the average official errors for the 10-yr period 1990-1999 (7, 11, 13, 16, and 19 kt, respectively), and were under-forecasts at all times, especially from 24 to 72 h. The first few forecasts kept Michael below hurricane strength, while latter forecasts weakened Michael down to a tropical storm too quickly. The SHIPS (Statistical Hurricane Intensity Prediction Scheme) intensity forecast model had similarly poor intensity forecasts.

d. Casualty and Damage Statistics

There were no reports of injuries or deaths. Light tree and structural damage was reported from Newfoundland. Most damage was confined mainly to home roofs and siding, and some trees blown down.

Table 1. Best track for Hurricane Michael, 17-19 October 2000.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
15 / 1200	30.0	71.2	1007	30	subtropical depression
15 / 1800	30.0	71.5	1006	30	"
16 / 0000	29.9	71.8	1005	35	subtropical storm
16 / 0600	29.9	71.9	1005	35	"
16 / 1200	29.7	71.7	1005	35	"
16 / 1800	29.8	71.4	1004	35	"
17 / 0000	29.9	71.1	1003	35	tropical storm
17 / 0600	29.8	71.0	1000	45	"
17 / 1200	29.8	70.9	995	55	"
17 / 1800	30.1	70.9	988	65	hurricane
18 / 0000	30.4	70.9	988	65	"
18 / 0600	30.8	70.8	986	65	"
18 / 1200	31.5	70.4	984	65	"
18 / 1800	32.6	69.5	979	70	"
19 / 0000	34.2	67.8	983	75	"
19 / 0600	36.3	65.5	986	65	"
19 / 1200	39.8	61.6	979	75	"
19 / 1800	44.0	58.5	965	85	"
20 / 0000	48.0	56.5	966	75	extratropical
20 / 0600	50.0	56.0	966	70	"
20 / 1200	51.0	53.5	968	65	"
20 / 1800	52.0	50.5	970	60	"
21 / 0000					absorbed by extratropical low
19 / 1800	44.0	58.5	965	85	minimum pressure
20 / 2300	47.6	56.7	965	85	landfall as an extratropical low

Table 2. Ship reports with winds of at least 34 kt for Hurricane Michael.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
16 / 0600	3ESU8	28.9	69.9	160/33	1007.0
17 / 1800	WGJT	26.1	75.3	310/37	1012.7
18 / 1500	VVML	32.2	67.9	180/35	1014.3
18 / 1500	WPGJ	30.9	70.7	270/36	1004.5
18 / 1800	VVML	32.0	68.2	180/45	1002.3
18 / 1800	WPGJ	31.7	71.0	310/35	1015.0
18 / 2100	VVML	31.8	68.4	220/50	1004.8
19 / 0000	LAVY4	34.9	67.4	120/37	999.0
19 / 0000	VVML	31.8	68.7	290/40	1009.3
19 / 0000	ZCBU8	44.0	64.2	110/47	1020.0
19 / 0300	LAVY4	34.8	68.3	340/36	missing
19 / 0600	ZCBU8	43.3	66.2	110/68	1008.0
19 / 0900	CY533	43.8	60.6	090/45	1004.4
19 / 1200	3FML3	41.4	55.0	180/39	1010.6
19 / 1200	3FRY9	38.1	60.4	180/57	1001.0
19 / 1200	CY533	43.8	60.6	130/37	998.7
19 / 1200	WPWH	39.6	56.3	180/35	1010.0
19 / 1200	WRYX	38.0	58.0	170/42	1007.0
19 / 1700	3EHR6	43.0	59.4	180/80	965.5
19 / 1800	3FRY9	38.2	58.5	260/38	1006.8
19 / 1800	C6FI9	43.3	60.3	270/40	974.0
19 / 1800	WPWH	39.8	58.4	250/38	1001.8
Extratropical					
19 / 2100	C6FI9	43.2	61.1	270/45	990.0
20 / 0000	C6FI9	43.2	61.7	270/35	1003.0
20 / 0000	MZGK7	44.3	55.9	220/52	991.5
20 / 0000	V7AP7	40.0	54.1	210/37	1009.0
20 / 0000	VCRT	46.1	50.5	180/48	992.0
20 / 0000	VCRZ	46.1	59.5	320/43	986.7
20 / 0600	3EHR6	42.6	63.3	300/35	1010.0
20 / 0600	C6FI9	43.1	63.4	270/40	1011.0
20 / 0600	MZGK7	44.7	58.1	250/46	998.4
20 / 0600	VCRT	46.2	52.0	230/58	987.0

Table 2 (continued). Ship reports with winds of at least 34 kt for Hurricane Michael.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
20 / 0600	VCRZ	46.9	59.5	300/39	995.7
20 / 1200	8PNK	44.5	60.5	290/35	1009.3
20 / 1200	LAQT2	42.1	54.0	270/40	1008.3
20 / 1200	MZGK7	44.5	60.7	280/40	1008.1
20 / 1200	V7AP7	40.4	58.9	300/35	1013.0
20 / 1200	VCRT	46.2	52.5	250/56	991.0
20 / 1500	G3130	51.1	58.5	330/34	993.9
20 / 1800	G3130	51.1	58.5	330/35	997.9
20 / 1800	SHIP	40.5	50.0	270/35	1011.5
20 / 1800	V7AP7	41.7	60.5	270/37	1016.0
20 / 1800	VCRT	46.2	53.2	270/60	996.0
20 / 1800	ZCAH2	40.6	50.0	270/35	1011.5

Table 2a. Buoy reports with winds of at least 34 kt for Hurricane Michael.

Date/Time (UTC)	Buoy call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
17 / 0000	41503 ^a	26.2	73.0	270/43	1011.9
17 / 0000	41505 ^a	26.7	65.1	/46	missing
18 / 0000	41501 ^a	27.2	71.9	290/45	1012.2
18 / 1200	41501 ^a	27.1	71.9	250/43	1013.6
19 / 1800	44139 ^b	44.3	57.4	140/43	983.5
19 / 2100	44255 ^b	47.3	57.4	040/37	976.1
20 / 0000	44139 ^b	44.3	57.4	230/43	992.0
20 / 0300	44139 ^b	44.3	57.4	260/35	998.4

a = drifting buoy

b = 10-min average wind; moored buoy

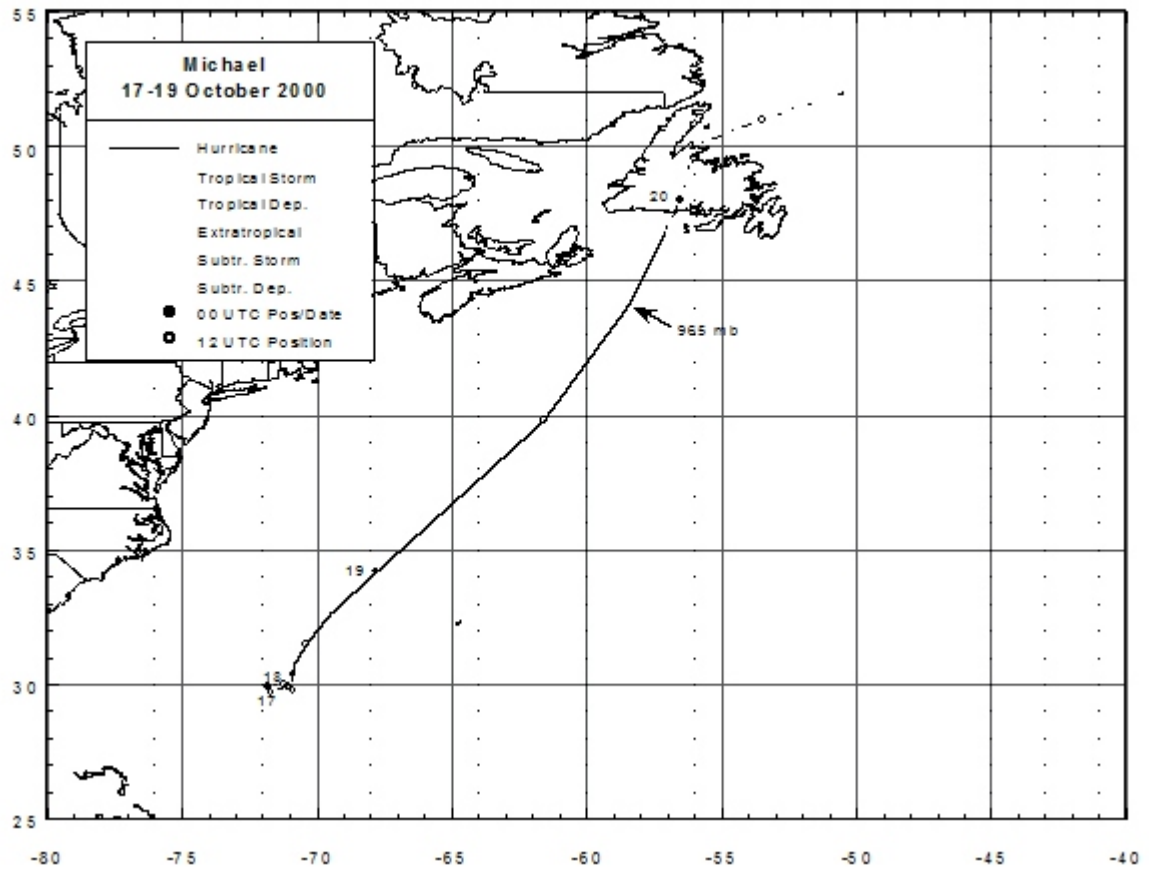


Figure 1. Best track positions for Hurricane Michael. Track during the extratropical stage is based on analyses from the NOAA Marine Prediction Center and Environment Canada weather service. Subtropical positions on 15-16 October are very close to the 17-18 October tropical positions due to the system being nearly stationary.

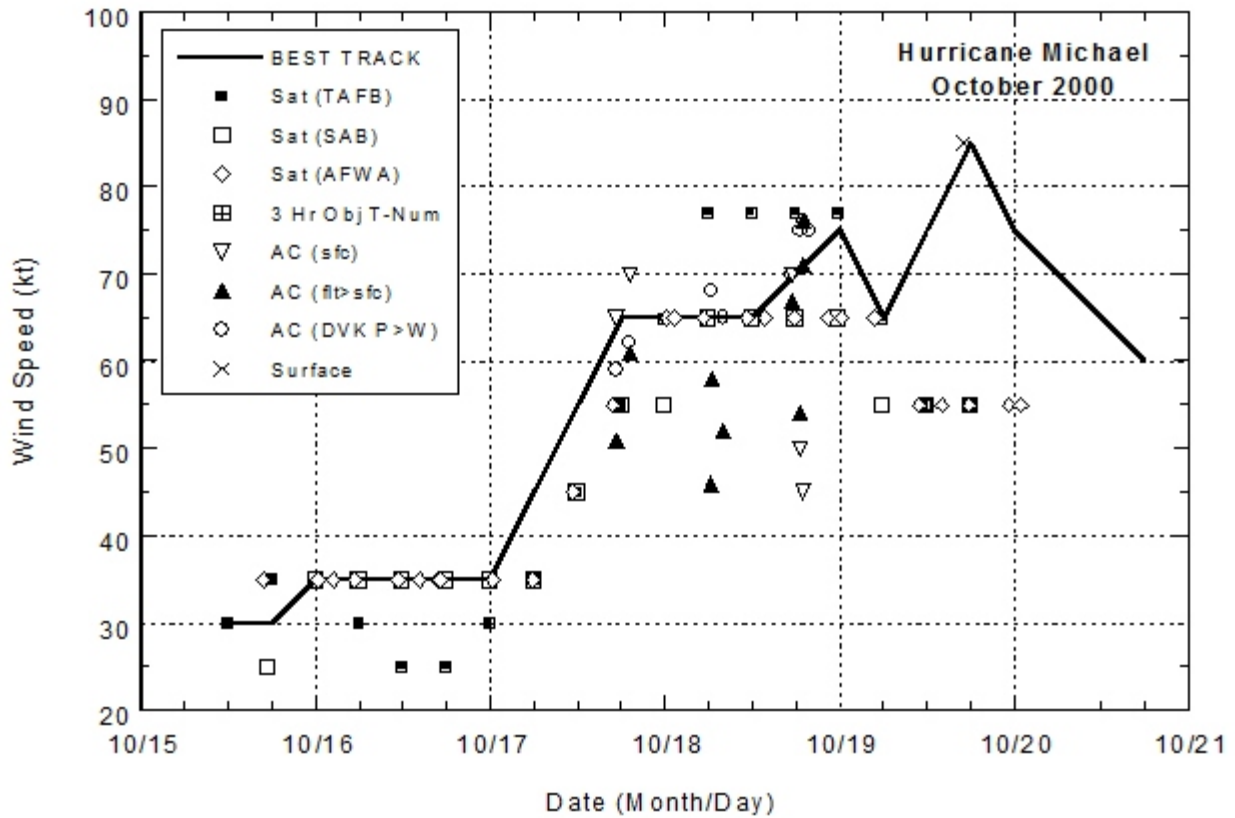


Figure 2. Best track maximum sustained surface wind speed curve for Hurricane, and the observations on which the best track curve is based. Aircraft observations have been adjusted for elevation using 80% and 85% reduction factors for observations from 850 mb and 1500 ft, respectively. Estimates during the extratropical stage are based on analyses from the NOAA Marine Prediction Center and Environment Canada weather service.

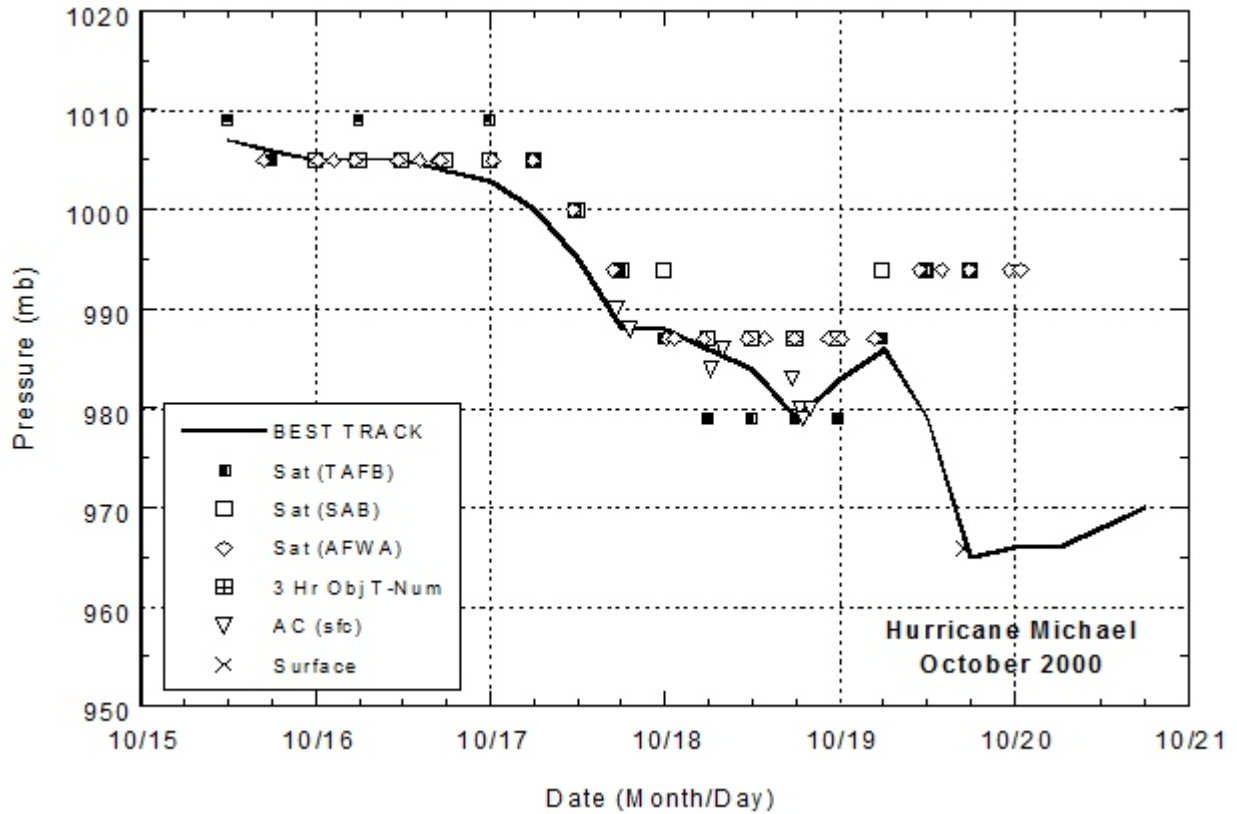


Figure 3. Best track minimum central pressure curve for Hurricane Michael, and the observations on which the best track curve is based. Estimates during the extratropical stage are based on analyses from the NOAA Marine Prediction Center and Environment Canada weather service.

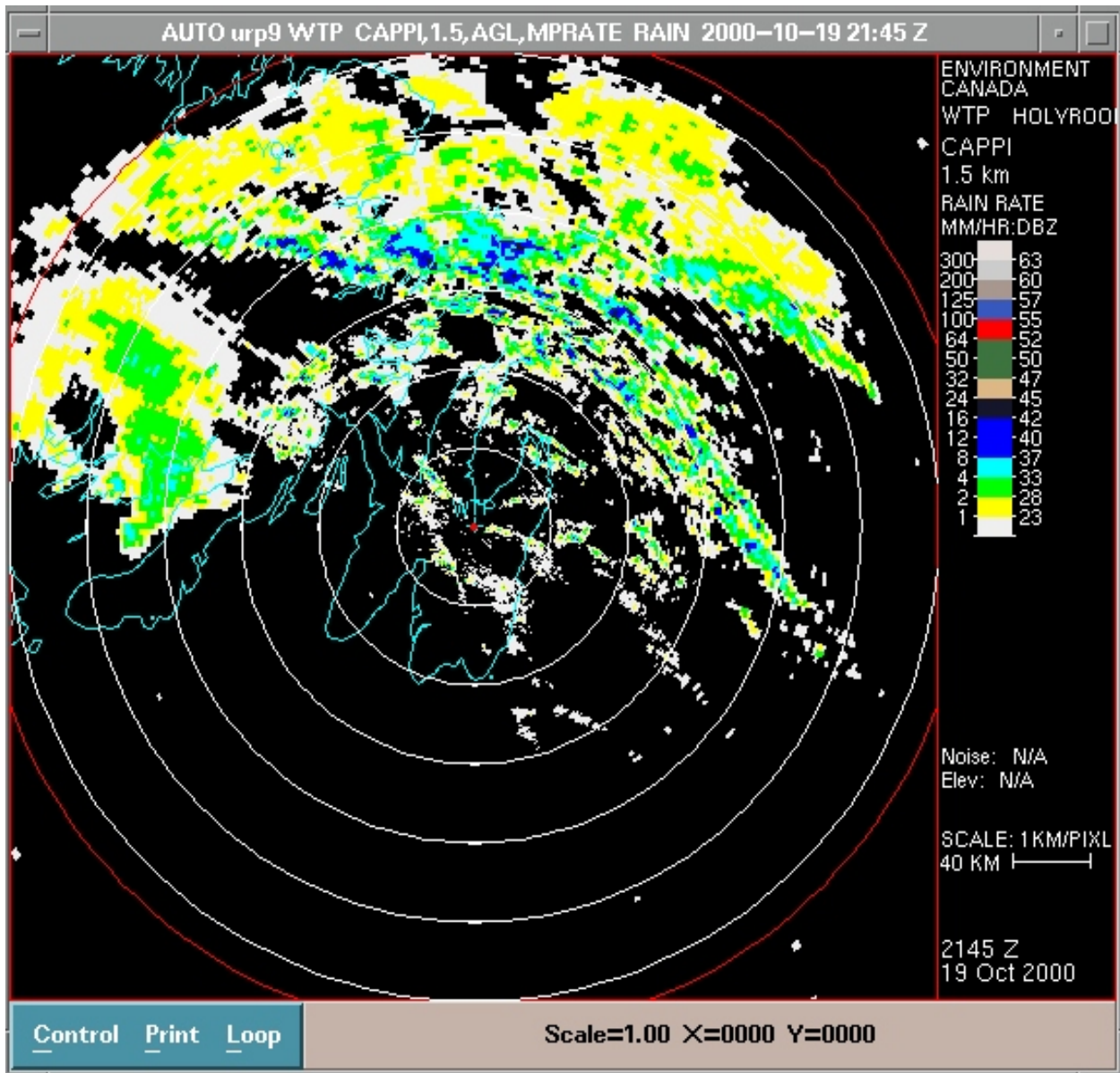


Figure 4. Holyrood, Newfoundland (WTP) 1.5 km AGL Constant Altitude Plan Position Indicator (CAPPI) image at 2145 UTC, 19 October 2000. Eye is located west-northwest near the fifth range ring (285°/210 km). Surface position of Michael was located west-southwest of the radar site off the edge of the display (image courtesy of the Environment Canada weather service).