Tropical Cyclone Report
Hurricane Norbert
(EP152008)
4-12 October 2008

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Norbert, the strongest October eastern North Pacific hurricane since Kenna in 2002, attained category four strength on the Saffir-Simpson Hurricane Scale before weakening and striking the west coast of the Baja California peninsula as a category two hurricane. It later struck mainland Mexico as a category one hurricane.

a. Synoptic History

Norbert originated out of a large and slow-moving area of low pressure that developed south of the Gulf of Tehuantepec on 28 September. The initial surface low appears to have been associated with a tropical wave that crossed Central America on 26-27 September, with a second tropical wave reaching the area on 2 October. The following day convection associated with the low became more concentrated and persistent, and it is estimated that a tropical depression formed around 0000 UTC 4 October, centered about 210 n mi south-southeast of Acapulco, Mexico.

The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1]. Initially nearly stationary, the depression soon began to move slowly westward to the south of a building mid-level high pressure ridge. Easterly vertical wind shear limited development, and the depression took 24 h to reach tropical storm strength, around 0000 UTC 5 October, when the system was centered about 170 n mi south-southwest of Acapulco. The easterly shear abated somewhat over the next couple of days, but Norbert continued to intensify only slowly, becoming a hurricane around 0600 UTC 7 October while centered about 270 n mi south-southwest of Manzanillo, Mexico.

Now moving west-northwestward around the periphery of the subtropical ridge, the hurricane began a period of rapid strengthening on 7 October. By midday, microwave imagery revealed a partially closed banding eyewall, and the cirrus outflow became better defined. Norbert intensified by 40 kt over the ensuing 24 h and reached its peak intensity of 115 kt (category four strength) near 1800 UTC 8 October. At this time the center was about 390 n mi south of Cabo San Lucas, Mexico.

[1] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

Norbert was still over warm waters and embedded within light vertical shear, however structural changes within the hurricane appear to have prevented additional strengthening. Microwave imagery around the time of peak intensity showed the eyewall of Norbert was surrounded by several well-defined spiral bands. By 0900 9 October, additional microwave passes indicated that the eyewall had eroded significantly, with more-circular (albeit not quite concentric) outer banding, while infrared imagery indicated that the core deep convection had weakened, suggesting the onset of an eyewall replacement cycle. By the time a reconnaissance aircraft arrived at the center of Norbert near 1800 UTC, the hurricane had weakened to category one strength, with maximum winds of near 70 kt.

On 10 October Norbert turned northward and its forward motion slowed when it reached the westward extent of the subtropical ridge. Wind shear was still light, and Norbert began to re-strengthen as it completed its eyewall replacement cycle. Norbert turned to the north-northeast ahead of a mid- to upper-level trough dropping southward over the southwestern United States, the hurricane's maximum winds reaching 100 kt near 0600 UTC 11 October. At this point the center of Norbert was about 160 n mi west of Cabo San Lucas. Turning northeastward and accelerating, Norbert weakened slightly as it approached Baja California, making landfall on the peninsula near Puerto Chale in the state of Baja California Sur, just southeast of Bahia Magdalena, around 1630 UTC 11 October. At the time of landfall, Norbert's maximum winds are estimated to have been near 90 kt (category two strength), making Norbert the strongest hurricane on record to strike the western Baja California coast.

Norbert crossed the peninsula and its center emerged into the Gulf of California around 2100 UTC. Strong vertical wind shear and Norbert's passage over land caused the hurricane to continue to weaken. Norbert reached the coast of mainland Mexico about 20 n mi east-southeast of Huatabampo in the state of Sonora near 0400 UTC 12 October, as a category one hurricane with estimated peak winds of 75 kt. The landfall location is also about 50 n mi north-northeast of Los Mochis. Norbert then continued moving northeastward and rapidly weakened, becoming a tropical storm within a few hours of making landfall and becoming a tropical depression by 1200 UTC that day. By 1800 UTC, the circulation had dissipated over the mountains of northeastern Mexico.

b. Meteorological Statistics

Observations in Norbert (Figs. 2 and 3) include satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), as well as flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from two flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites, the NASA Tropical Rainfall Measuring Mission (TRMM), the NASA QuikSCAT, and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in tracking Norbert.

The estimated peak intensity of Norbert at 1800 UTC 8 October was based on subjective Dvorak classifications from TAFB and SAB. When the first reconnaissance aircraft reached

Norbert 24 h later, they found a much weaker system than that suggested by the concurrent satellite classifications (see Figure 2). This raises the possibility that the satellite-based intensity estimates may have been high at other times during Norbert's life cycle, in particular when Norbert is assessed to have reached category four strength, and when it reacquired category three status. Given the structural changes that were occurring during the period of the aircraft observations, however, it is assumed that the satellite/aircraft disconnect was mostly confined to the period when Norbert's inner eyewall was eroding.

There were no believable ship reports of winds of tropical storm force associated with Norbert, and land-based observations from the affected areas are extremely limited. Sustained winds of 50 kt, with gusts to 60 kt, were reported at the airport at Los Mochis (MMLM) around 0200 UTC 12 October. The maximum 24 h reported rainfall was 4.78 in (121.3 mm) at Ciudad Constitucion on the Baja California peninsula.

c. Casualty and Damage Statistics

Information from meteorological and civil defense officials in Mexico indicates there were five deaths directly associated with Norbert in Alamos, Sonora. These deaths, two women and three men, were associated with river floodwaters.

Media reports indicate that nearly half of the homes were totally or partially damaged, mostly from roof damage, on the islands of Margarita and Magdalena, near the first landfall site, with electricity reportedly cut off to roughly 20,000 homes in Baja California. Rushing, knee-deep water was reported in the town of Ciudad Constitucion. Unspecified surge flooding was reported in the fishing town of Puerto San Carlos.

d. Forecast and Warning Critique

The genesis of Norbert was reasonably well anticipated. The disturbance from which Norbert developed was introduced in the Tropical Weather Outlook (TWO) five days prior to genesis. Experimental 48-h genesis probabilities first reached the "high" category (greater than 50% chance of genesis within 48 h) a little early - about 60 h prior to genesis.

Official track forecasts for Norbert were outstanding. A verification of official and guidance model track forecasts is given in Table 2. Average official track errors for Norbert (with the number of cases in parentheses) were 24 (33), 33 (31), 40 (29), 50 (27), 80 (23), 94 (19), and 130 (15) n mi for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. These errors are substantially lower than the average 5-yr official track errors (Table 2). Although no individual dynamical model performed particularly well with Norbert, the consensus models (e.g., TVCN) performed exceptionally. The GFS performed unusually poorly; early on it over-developed a disturbance to the east of Norbert and consequently forecast an interaction between the two systems that did not occur. The GFS was also one of the last models to forecast Norbert's capture by the upper-level trough over the southeastern United States.

A verification of official and guidance model intensity forecasts is given in Table 3. Average official intensity errors were 10, 16, 17, 17, 16, 21, and 22 kt for the 12, 24, 36, 48, 72, 96, and 120 h forecasts, respectively. For comparison, the average 5-yr official intensity errors are 6, 10, 14, 16, 19, 19, and 19 kt, respectively. That the official errors were somewhat above the 5-yr means can be attributed to the large swings in intensity that occurred during the last half of Norbert's life cycle – changes that are generally not captured by official forecasts (e.g., Fig. 4). The objective intensity guidance for Norbert had similar difficulties. The significant strengthening of Norbert on 7-8 October was indicated at times by the SHIPS rapid intensification (RI) index, although the index was inconsistent.

Watches and warnings issued by the government of Mexico in association with Norbert are given in Table 4.

Table 1. Best track for Hurricane Norbert, 4-12 October 2008.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
04 / 0000	13.5	99.1	1006	30	tropical depression
04 / 0600	13.8	99.0	1006	30	"
04 / 1200	14.0	99.5	1006	30	"
04 / 1800	14.1	100.1	1006	30	"
05 / 0000	14.1	100.6	1005	35	tropical storm
05 / 0600	14.0	101.1	1003	40	"
05 / 1200	13.9	101.7	1000	50	"
05 / 1800	13.9	102.4	1000	50	"
06 / 0000	13.9	103.0	1000	50	"
06 / 0600	14.0	103.6	996	55	"
06 / 1200	14.2	104.3	993	55	"
06 / 1800	14.4	104.9	990	60	"
07 / 0000	14.6	105.4	988	60	"
07 / 0600	14.9	106.0	987	65	hurricane
07 / 1200	15.0	106.8	985	70	"
07 / 1800	15.2	107.7	980	75	"
08 / 0000	15.5	108.6	970	90	"
08 / 0600	15.8	109.5	960	100	"
08 / 1200	16.1	110.2	952	110	"
08 / 1800	16.4	110.9	945	115	"
09 / 0000	16.8	111.6	948	110	"
09 / 0600	17.2	112.1	954	100	"
09 / 1200	17.6	112.5	960	85	"
09 / 1800	18.0	112.8	973	70	"
10 / 0000	18.6	113.1	973	70	"
10 / 0600	19.3	113.3	973	70	"
10 / 1200	20.0	113.5	970	75	"
10 / 1800	20.9	113.5	968	80	"
11 / 0000	21.8	113.2	960	90	"
11 / 0600	22.8	112.8	953	100	"
11 / 1200	23.7	112.3	954	95	"
11 / 1800	24.6	111.4	957	90	"
12 / 0000	25.8	110.2	961	80	"
12 / 0600	27.0	108.7	975	65	"

12 / 0700	27.2	108.4	978	60	tropical storm
12 / 1200	28.3	107.0	995	30	tropical depression
12 / 1800					dissipated
11 / 1630	24.4	111.6	956	90	Landfall near Puerto Chale, Mexico
12 / 0400	26.6	109.3	964	75	Landfall 20 n mi ESE of Huatabampo, Mexico
08 / 1800	16.4	110.9	945	115	minimum pressure

Table 2. Track forecast evaluation (heterogeneous sample) of selected models for Hurricane Norbert, 4-12 October 2008. Forecast errors (n mi) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
CLP5	39 (33)	75 (31)	122 (29)	165 (27)	239 (23)	306 (19)	350 (15)
GFNI	34 (30)	57 (28)	75 (26)	90 (24)	124 (19)	157 (14)	212 (10)
GFDI	28 (33)	46 (31)	53 (29)	65 (27)	127 (23)	206 (19)	212 (15)
HWFI	39 (33)	62 (31)	82 (29)	104 (27)	168 (22)	288 (17)	439 (13)
GFSI	35 (33)	48 (31)	65 (29)	92 (27)	165 (23)	297 (19)	458 (13)
AEMI	35 (33)	59 (31)	86 (29)	118 (27)	180 (23)	254 (19)	317 (15)
NGPI	27 (30)	46 (29)	52 (27)	57 (25)	116 (21)	227 (17)	244 (13)
UKMI	34 (32)	49 (30)	66 (28)	78 (26)	126 (22)	185 (18)	217 (14)
EGRI	30 (30)	43 (28)	57 (26)	68 (24)	110 (20)	158 (16)	201 (12)
EMXI	26 (23)	43 (21)	60 (21)	73 (20)	112 (17)	172 (15)	224 (13)
BAMD	45 (33)	81 (31)	110 (29)	116 (27)	130 (23)	168 (19)	305 (15)
BAMM	33 (33)	50 (31)	74 (29)	101 (27)	164 (23)	255 (19)	408 (15)
BAMS	40 (31)	67 (29)	98 (27)	122 (25)	193 (21)	312 (18)	462 (14)
LBAR	37 (32)	87 (30)	137 (28)	181 (26)	342 (22)	634 (19)	987 (14)
TVCN	24 (33)	**32 (31)**	**34 (29)**	**41 (27)**	**59 (23)**	100 (19)	**128 (15)**
GUNA	**21 (29)**	**27 (28)**	**33 (26)**	**43 (24)**	**66 (20)**	**87 (16)**	**99 (10)**
FSSE	**21 (29)**	**30 (27)**	**33 (25)**	**42 (23)**	**63 (19)**	**73 (15)**	**114 (11)**
OFCL	24 (33)	33 (31)	40 (29)	50 (27)	80 (23)	94 (19)	130 (15)
NHC Official (2003-2007 mean)	31.9 (1282)	55.1 (1129)	77.4 (979)	97.9 (849)	136.2 (620)	180.1 (439)	226.1 (293)

Table 3. Intensity forecast evaluation (heterogeneous sample) of selected models for Hurricane Norbert, 4-12 October 2008. Forecast errors (kt) are followed by the number of forecasts in parentheses. Errors smaller than the NHC official forecast are shown in boldface type.

Forecast Technique	Forecast Period (h)						
	12	24	36	48	72	96	120
OCD5	10.1 (33)	**15.4 (31)**	19.0 (29)	19.4 (27)	20.4 (23)	31.2 (19)	33.9 (15)
GHMI	9.6 (33)	**13.7 (31)**	**15.1 (29)**	**16.0 (27)**	20.5 (23)	31.8 (19)	32.5 (15)
HWFI	11.9 (33)	17.2 (31)	21.0 (29)	21.1 (27)	19.3 (22)	**16.4 (17)**	27.5 (13)
LGEM	**8.8 (33)**	**15.5 (31)**	20.4 (29)	20.7 (27)	22.7 (23)	30.1 (19)	33.1 (15)
DSHP	**9.1 (33)**	16.3 (31)	19.6 (29)	19.7 (27)	18.8 (23)	26.5 (19)	26.9 (15)
FSSE	10.3 (29)	16.4 (27)	19.2 (25)	18.2 (23)	19.3 (19)	**19.9 (15)**	25.5 (11)
ICON	**8.2 (33)**	**14.2 (31)**	17.5 (29)	17.6 (27)	16.5 (22)	**20.3 (17)**	25.7 (13)
OFCL	9.5 (33)	16.0 (31)	17.2 (29)	16.5 (27)	16.3 (23)	20.5 (19)	22.3 (15)
NHC Official (2003-2007 mean)	6.2 (1282)	10.4 (1129)	13.9 (979)	16.3 (848)	18.7 (620)	19.2 (439)	19.1 (293)

Table 4. Watch and warning summary for Hurricane Norbert, 4-12 October 2008.

Date/Time (UTC)	Action	Location
10 / 0300	Hurricane Watch issued	Puerto San Andresito to Loreto
10 / 0600	Hurricane Watch modified to	Loreto to Agua Blanca
10 / 0600	Hurricane Warning issued	Puerto San Andresito to Agua Blanca
10 / 1500	Tropical Storm Watch issued	Topolobampo to Guaymas
10 / 1500	Tropical Storm Warning issued	Agua Blanca to Mulege
10 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Topolobampo to Guaymas
10 / 2100	Tropical Storm Watch changed to Hurricane Watch	Topolobampo to Guaymas
11 / 0300	Tropical Storm Warning changed to Hurricane Warning	Topolobampo to Guaymas
11 / 0300	Tropical Storm Warning modified to	La Paz to Agua Blanca
11 / 0300	Hurricane Watch discontinued	Topolobampo to Guaymas
11 / 0300	Hurricane Watch modified to	La Paz to Agua Blanca
11 / 0300	Hurricane Warning issued	La Paz to Loreto
11 / 2100	Tropical Storm Warning issued	Topolobampo to Altata
12 / 0300	Tropical Storm Warning discontinued	La Paz to Agua Blanca
12 / 0300	Tropical Storm Warning discontinued	Loreto to Mulege
12 / 0300	Hurricane Watch discontinued	All
12 / 0300	Hurricane Warning discontinued	Puerto San Andresito to Agua Blanca
12 / 0300	Hurricane Warning discontinued	La Paz to Loreto
12 / 0900	Tropical Storm Warning discontinued	All
12 / 0900	Hurricane Warning discontinued	All

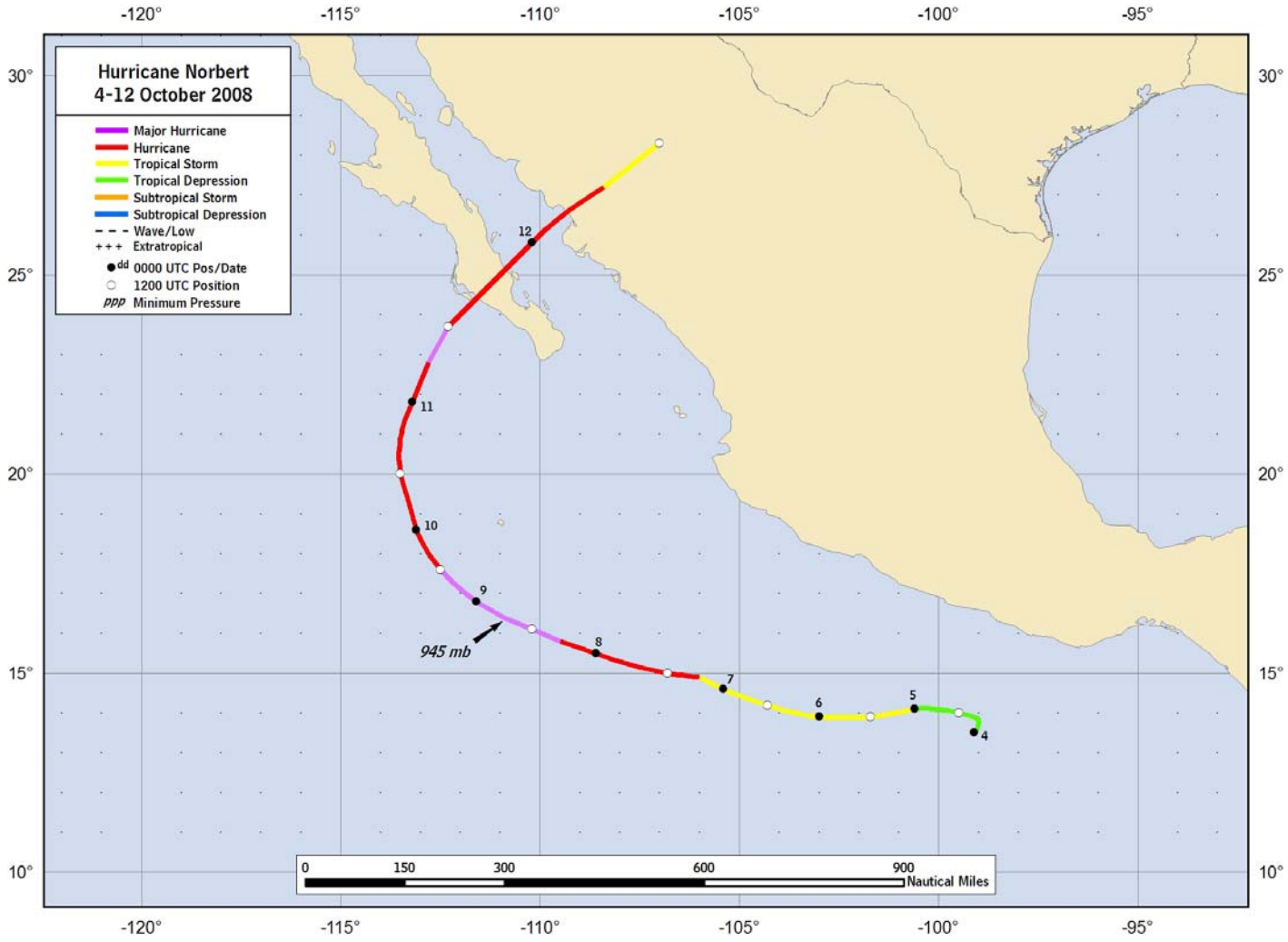

Figure 1. Best track positions for Hurricane Norbert, 4-12 October 2008.

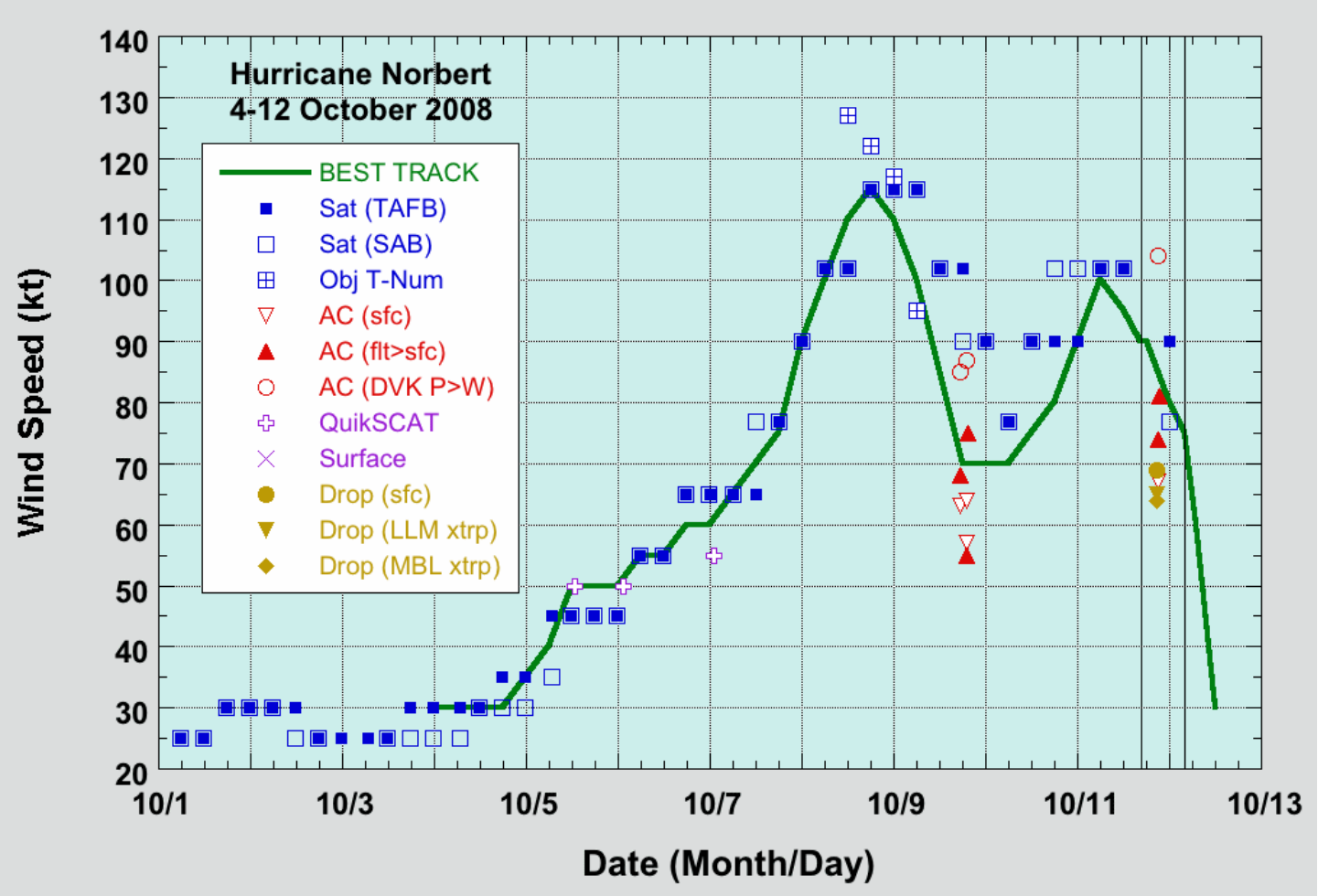

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Norbert, 4-12 October 2008. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde 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). Objective (ADT) Dvorak estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines indicate landfalls.

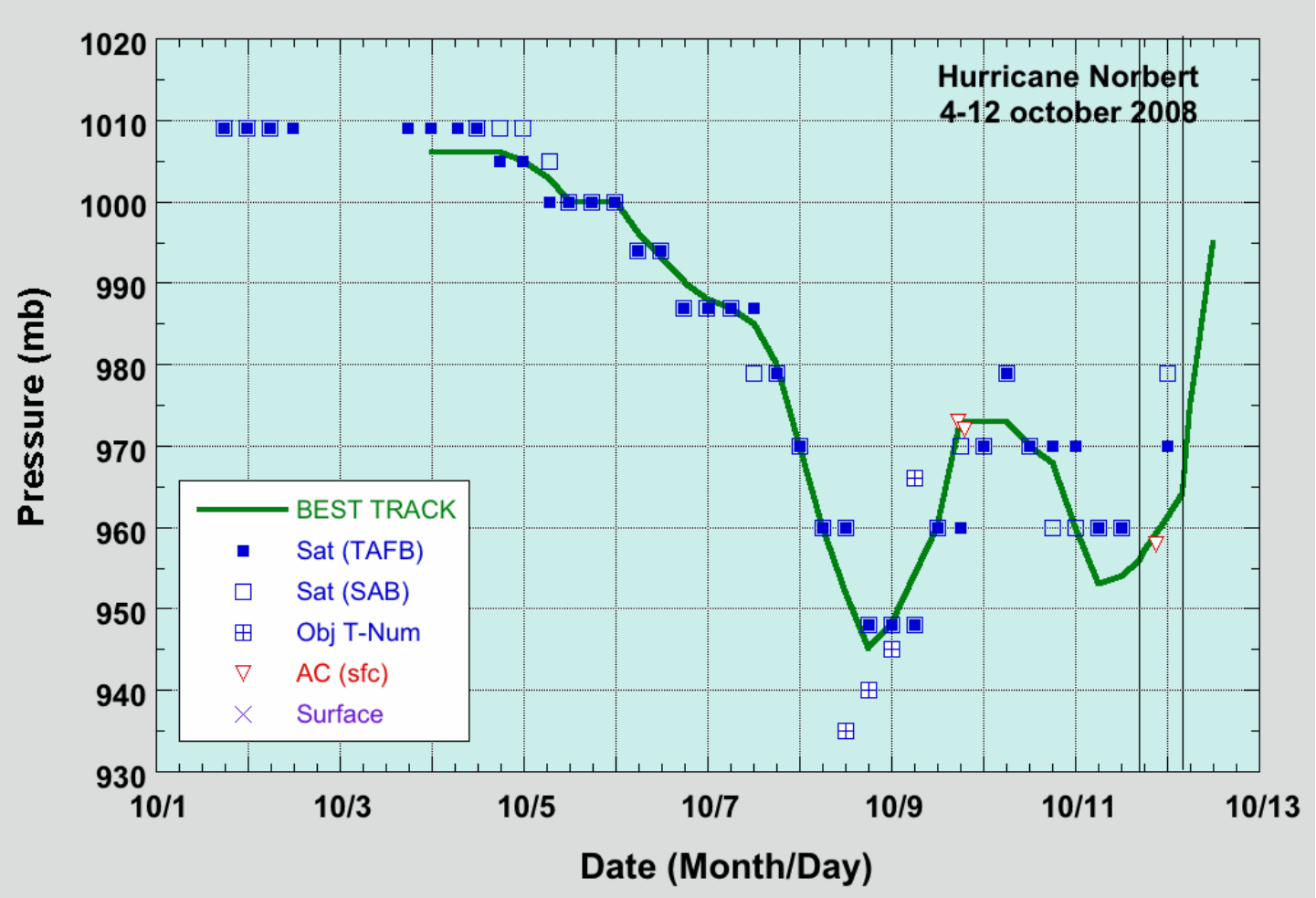

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Norbert, 4-12 October 2008. Objective (ADT) Dvorak estimates represent linear averages over a three-hour period centered on the nominal observation time. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines indicate landfalls.

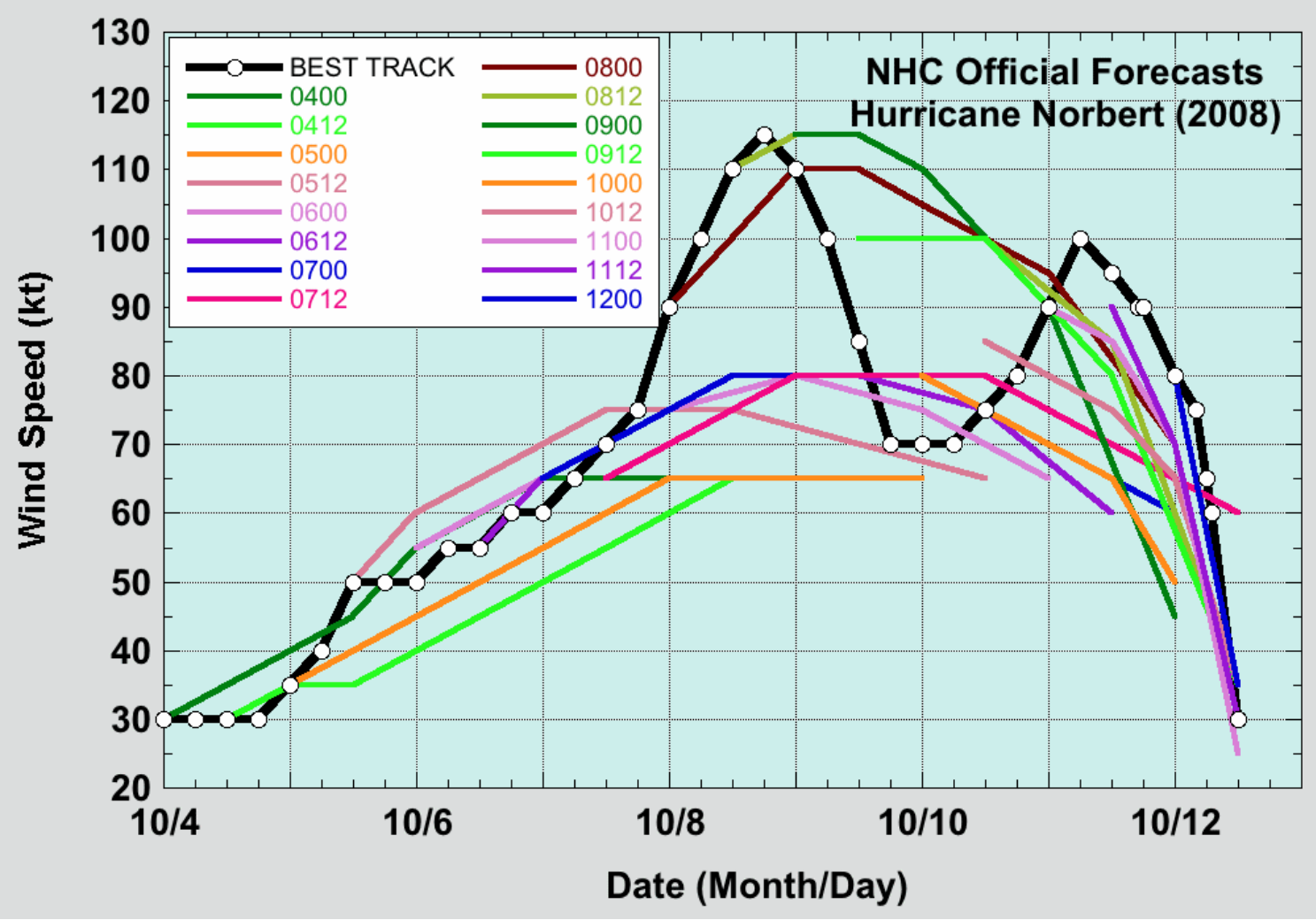

Figure 4. Selected official intensity forecasts for Hurricane Norbert, 4-12 October 2008. The best track intensity is given by the thick solid line.