Tropical Cyclone Report
Hurricane Otto (AL172010)
6-10 October 2010

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Otto was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that produced heavy rainfall over portions of the northeastern Caribbean islands.

a. Synoptic History

Otto developed from a tropical wave that departed the west coast of Africa on 26 September. The wave produced little shower activity for the next few days while over the tropical eastern Atlantic Ocean. Thunderstorms increased along the wave axis on 29 September as the system began interacting with an upper-level trough over the central Atlantic Ocean. Although the associated deep convection continued for several more days, a closed surface circulation did not exist during that time. The wave moved over the northern Leeward Islands early on 4 October and surface observations and scatterometer data indicate that the system consisted of a broad and highly elongated trough of low pressure. The trough gradually sharpened, and satellite data along with surface observations suggest that a well-defined circulation developed by 0600 UTC 6 October, then centered about 230 n mi north-northwest of San Juan, Puerto Rico. Since the surface low was underneath an upper-level trough and had a large radius of maximum wind, it has been classified a subtropical depression at the time of genesis. The "best track" chart of Otto'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].

The subtropical depression strengthened at a quick pace after genesis and became a subtropical storm within the next 6 h. While intensifying, the system slowed in forward speed and turned toward the north-northwest. Data from an Air Force Reserve reconnaissance aircraft indicate that Otto reached an intensity of 55 kt by 0000 UTC 7 October. Shortly thereafter, banding features associated with the storm became less organized and satellite intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB) suggest that Otto weakened during the overnight and early morning hours of 7 October as it drifted northward in weak steering currents. Although the storm weakened, deep convection began to form near the center early on 7 October, and Advanced Microwave Sounding Unit (AMSU) vertical temperature profiles indicate that a warm core had developed vertically. Otto became a tropical storm at 1200 UTC 7 October. After the transition, Otto went through another intensification period. The cyclone became a hurricane by 1200 UTC 8 October, and reached its

[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.

maximum intensity of 75 kt about 12 h later. During that time, Otto accelerated toward the northeast under the influence of deep-layer southwesterly flow. An increase in vertical wind shear caused the cyclone to weaken on 9 October, and Otto fell below hurricane strength by that evening. The storm lost tropical characteristics by 0600 UTC 10 October, while located about 900 n mi east-northeast of Bermuda. A sequence of visible satellite images shows the evolution of Otto (Fig. 4).

The extratropical cyclone persisted for about four days while weakening gradually, initially racing northeastward but then slowing and turning southeastward near the Azores on 12 and 13 October. The system lost its frontal boundaries by 0600 UTC 14 October and degenerated to a low-level cloud swirl by that time. The weak low slowed further and eventually dissipated about 250 n mi west of Morocco around 0000 UTC 18 October.

b. Meteorological Statistics

Observations in Otto (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the TAFB and SAB. Observations also include flight-level and stepped frequency microwave radiometer (SFMR) from one flight by 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) and Aqua, the European Space Agency's Advanced Scatterometer (ASCAT), the U.S. Navy's WindSat, and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Otto.

The estimated peak intensity of 75 kt at 0000 and 0600 UTC 9 October is based on a blend of objective and subjective satellite intensity estimates.

There were no ship reports of tropical-storm-force winds in association with Otto when it was a tropical or subtropical cyclone.

c. Casualty and Damage Statistics

Heavy rainfall associated with Otto and its precursor disturbance occurred from 4-8 October over the eastern Caribbean. The heavy rains caused significant damage to portions of the northeastern Caribbean islands, including Puerto Rico and the U.S. Virgin Islands. Mudslides overturned cars, toppled power lines, flooded homes, and washed out roads. The British Virgin Islands were particularly hard hit, and this event was called the worst flooding in its history by the media. Rainfall totals exceeding 15 inches were measured across the northeastern Caribbean islands (Table 2 and Fig. 5). No casualties were reported.

d. Forecast and Warning Critique

The precursor disturbance of Otto was introduced in the Tropical Weather Outlook with a low (< 30%) chance of formation at 1800 UTC 28 September, about eight days prior to genesis. The probability of genesis was raised to medium (30-50%) at 1200 UTC 30 September, but was dropped back to the low category at 0000 UTC 2 October. The probability of formation was once again elevated to medium 30 h prior to genesis and raised to the high category (> 50%) 18 h before development occurred.

A verification of NHC official track forecasts for Otto is given in Table 3a. Official forecast track errors were much lower than the mean official errors for the previous five-year period at all available forecast times. The climatology and persistence model (OCD5) errors were about two times larger than the previous five-year average at 24 h and beyond. This implies that Otto was a difficult cyclone to forecast and that the official track forecasts were exceptionally good. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The only model that consistently beat the official forecast was the ECMWF (EMXI), which had lower errors at all times except 36 h. The multi-model corrected consensus (TVCC) was comparable to the official forecast.

A verification of NHC official intensity forecasts for Otto is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the previous five-year period at all time periods. The climatology and persistence model (OCD5) errors were generally larger than the previous five-year average. This indicates that the official intensity forecasts were also quite skillful, since Otto was a more difficult than average cyclone to forecast. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The official forecast performed better than any model through 36 h. However, the statistical-dynamical Decay SHIPS (DSHP) and LGEM models beat the official forecast at 48 h and 72 h.

Table 1. Best track for Hurricane Otto, 6-10 October 2010.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
06 / 0600	22.0	67.2	1000	30	subtropical depression
06 / 1200	22.6	67.8	995	40	subtropical storm
06 / 1800	23.0	68.1	991	50	"
07 / 0000	23.2	68.2	989	55	"
07 / 0600	23.4	68.3	990	50	"
07 / 1200	23.6	68.3	994	45	tropical storm
07 / 1800	23.8	67.8	992	50	"
08 / 0000	24.0	67.0	989	55	"
08 / 0600	24.4	66.1	986	60	"
08 / 1200	25.2	64.8	983	65	hurricane
08 / 1800	26.2	63.3	980	70	"
09 / 0000	27.2	61.7	976	75	"
09 / 0600	28.5	59.7	978	75	"
09 / 1200	30.0	57.3	981	70	"
09 / 1800	31.4	54.3	985	65	"
10 / 0000	32.7	50.9	988	60	tropical storm
10 / 0600	34.3	47.0	988	55	extratropical
10 / 1200	36.4	42.6	988	55	"
10 / 1800	38.2	38.1	988	55	"
11 / 0000	40.3	33.8	992	50	"
11 / 0600	42.0	30.8	995	45	"
11 / 1200	43.1	28.1	998	40	"
11 / 1800	43.5	26.3	998	40	"
12 / 0000	43.4	25.3	1002	35	"
12 / 0600	42.4	24.6	1004	35	"
12 / 1200	41.4	24.0	1004	35	"
12 / 1800	40.3	23.5	1006	35	"
13 / 0000	39.3	23.0	1004	35	"
13 / 0600	38.4	22.7	1004	35	"
13 / 1200	37.6	22.6	1004	35	"
13 / 1800	36.7	22.4	1004	35	"
14 / 0000	35.8	22.2	1004	35	"
14 / 0600	35.0	22.0	1005	30	low
14 / 1200	34.4	21.4	1005	30	"
14 / 1800	34.0	20.6	1005	30	"
15 / 0000	33.8	19.9	1006	30	"
15 / 0600	33.6	19.2	1006	30	"
15 / 1200	33.4	18.5	1006	30	"
15 / 1800	33.2	17.8	1006	30	"

16 / 0000	33.0	17.1	1006	25	"
16 / 0600	32.8	16.5	1006	25	"
16 / 1200	32.6	15.9	1007	25	"
16 / 1800	32.4	15.3	1007	25	"
17 / 0000	32.3	14.7	1008	25	"
17 / 0600	32.1	14.5	1010	25	"
17 / 1200	31.9	14.6	1010	20	"
17 / 1800	31.7	14.7	1012	20	"
18 / 0000					dissipated
09 / 0000	27.2	61.7	976	75	minimum pressure

Table 2. Selected surface observations for Hurricane Otto, 6-10 October 2010, and its precursor disturbance.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Buoys								
42060 (16.50 N -63.50 W)	06/2025	1006.6	06/1733	42	47			
41046 (23.84 N 70.87 W)	07/0704	999.8	07/0139	29	33			
41047 (27.47 N 71.49 W)	07/0739	1005.8	07/1547	31	35			
41049 (27.50 N 63.00 W)	08/2125	997.4	08/2115	37	47			
Puerto Rico								
Río Portugués								15.63
Lago Patillas, Ponce								15.55
Río Inabon, Ponce								14.85
Lago Cerillos, Ponce								12.48
Río Cerillos, Ponce								11.65
Aibonito								10.94
Patillas								10.41
Vieques								10.34
Río Coamo								9.84
San Juan								3.10
St. Croix								
Cotton Valley								7.10
Montpellier								8.81
Christiansted Airport (TISX)								7.10
St. Thomas								
Charlotte Amalie (TIST)								12.94
Red Hook								8.75
St. Maarten								
Prinses Juliana Airport (TNCM)								4.40
Antigua								
Coolidge (TAPA)								7.70

Dominica								
Dominca Cane Field (TDCF)								4.75
Guadeloupe								
Le Raizet (TFFR)								2.90
St. Kitts								
Golden Rock Airport (TKPK)								12.15

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Otto, 6-10 October 2010. Mean errors for the five-year period 2005-9 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Otto)	**21.3**	**33.3**	**45.6**	**40.4**	**72.1**		
OCD5 (Otto)	55.5	152.6	290.8	452.4	674.6		
Forecasts	14	12	10	8	4		
OFCL (2005-9)	31.8	53.4	75.4	96.8	143.8	195.6	252.1
OCD5 (2005-9)	46.9	97.3	155.4	211.6	304.8	387.9	467.8

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Otto, 6-10 October 2010. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 3a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	21.5	35.3	52.3	40.6	84.7		
GFSI	25.1	35.6	67.4	85.9	110.3		
GHMI	32.7	56.6	89.2	118.5	91.4		
HWFI	29.6	49.3	90.4	128.9	194.0		
GFNI	32.9	59.4	85.2	110.2	288.8		
NGPI	34.7	60.2	97.7	138.0	238.4		
EMXI	**20.1**	**27.5**	**44.5**	43.1	**37.0**		
AEMI	24.4	38.5	59.4	60.0	**57.8**		
TVCN	25.4	39.3	60.6	58.0	89.7		
TVCC	23.5	**32.6**	**50.5**	47.5	89.1		
LBAR	37.5	84.1	134.6	157.1	182.3		
BAMD	40.4	76.6	128.2	190.1	312.5		
BAMM	28.9	53.3	97.1	109.6	113.7		
BAMS	56.1	114.8	185.3	221.1	303.6		
NAMI	36.9	61.8	111.6	221.3	411.0		
Forecasts	11	9	7	5	2	0	0

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Otto, 6-10 October 2010. Mean errors for the five-year period 2005-9 are shown for comparison. Official errors that are smaller than the five-year means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Otto)	**6.4**	**8.3**	**8.0**	**10.0**	**15.0**		
OCD5 (Otto)	9.6	11.4	12.5	10.8	15.3		
Forecasts	14	12	10	8	4		
OFCL (2005-9)	7.0	10.7	13.1	15.2	18.6	18.7	20.1
OCD5 (2005-9)	8.6	12.5	15.8	18.2	21.0	22.7	21.7

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Otto, 6-10 October 2010. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	5.8	8.2	8.3	9.3	10.0		
OCD5	9.1	11.4	13.1	10.4	12.0		
DSHP	8.6	11.4	12.7	**6.7**	**9.0**		
LGEM	9.2	12.4	13.7	**9.0**	**9.3**		
HWFI	9.5	11.9	13.8	10.9	17.3		
GHMI	9.5	10.8	13.6	13.1	20.7		
GFNI	7.7	8.2	11.3	13.9	19.3		
Forecasts	13	11	9	7	3	0	0

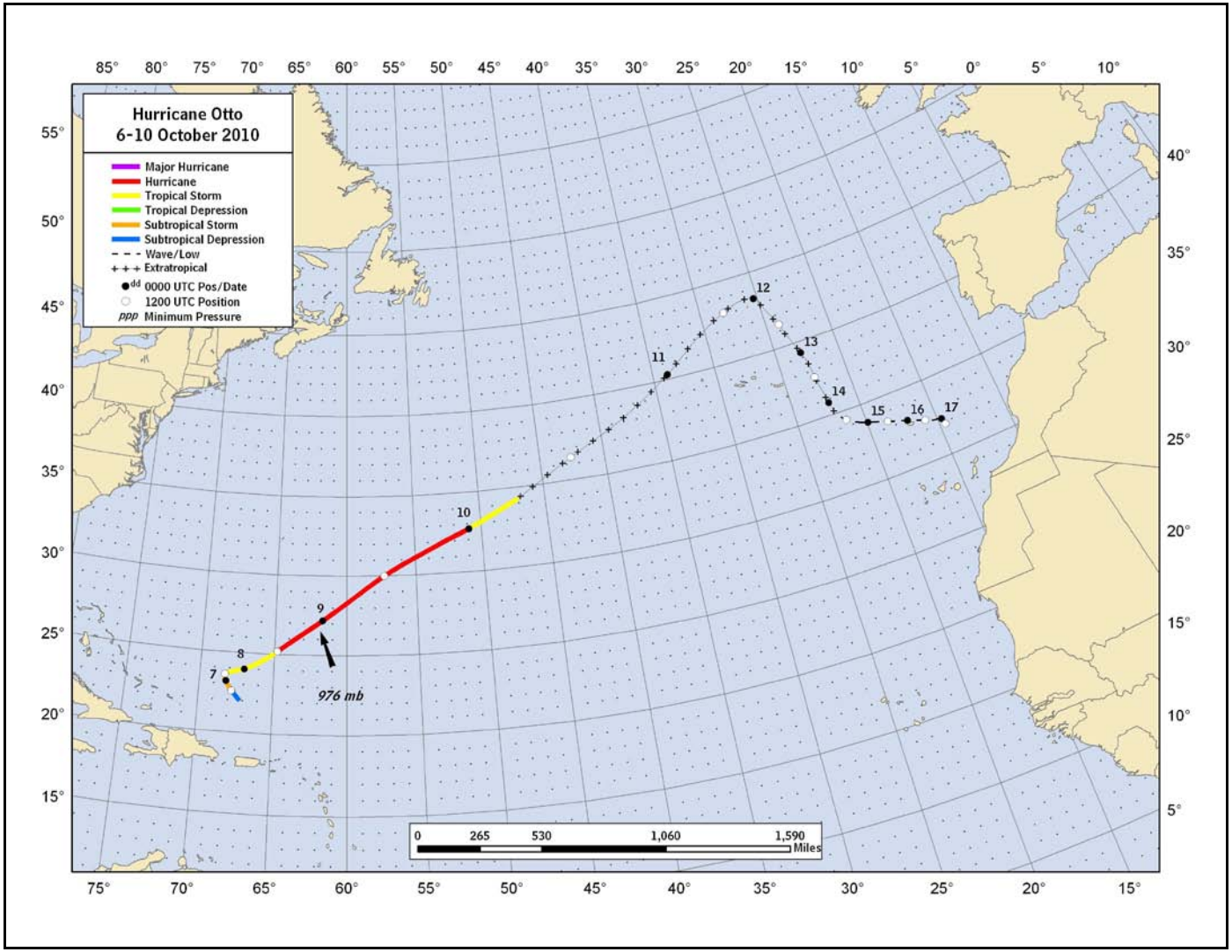

Figure 1. Best track positions for Hurricane Otto, 6-10 October 2010. Track during the extratropical stage is based on analyses from the NOAA Ocean Prediction Center.

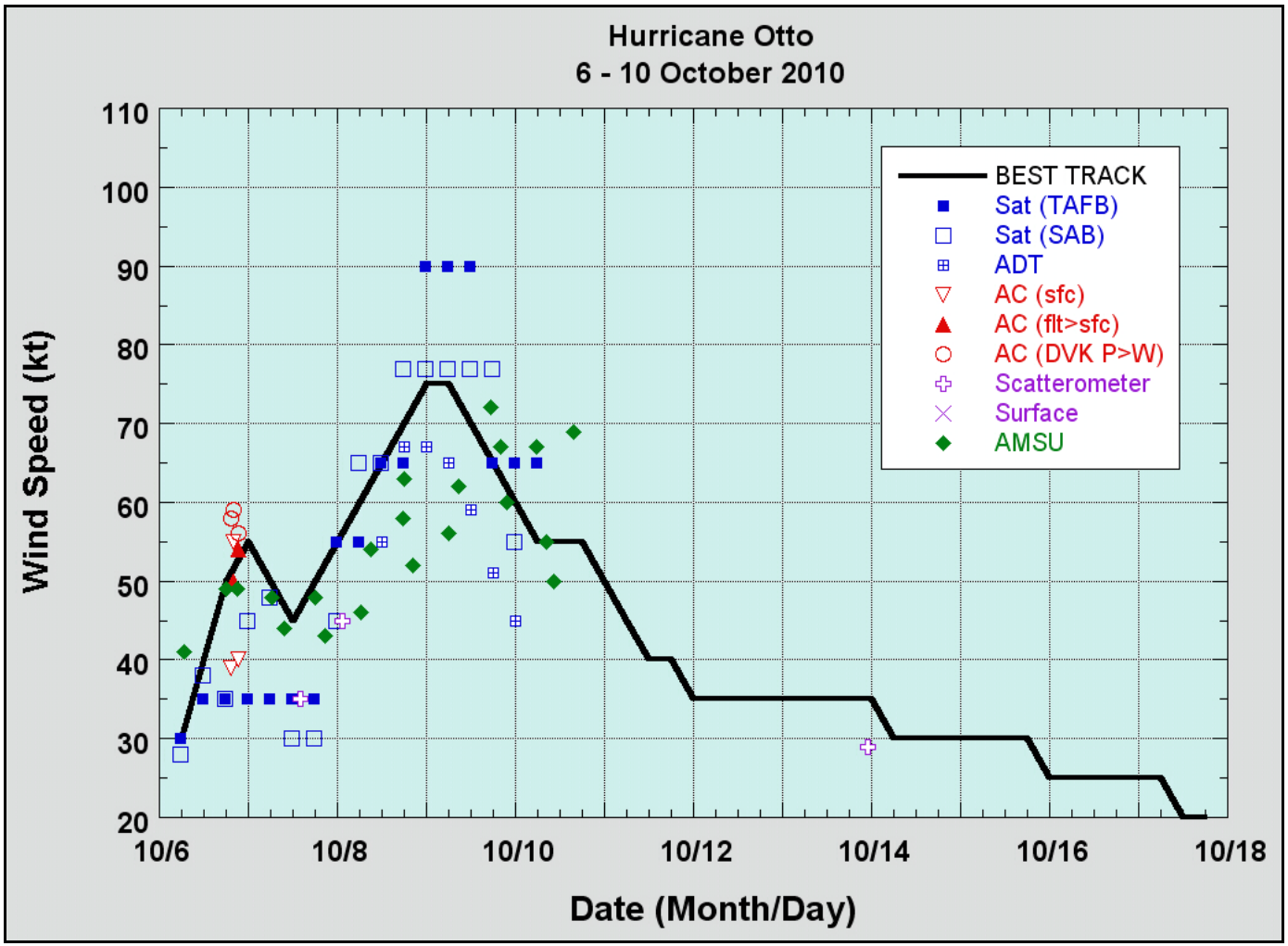

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Otto, 6-10 October 2010. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. Estimates during the extratropical stage are based on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC.

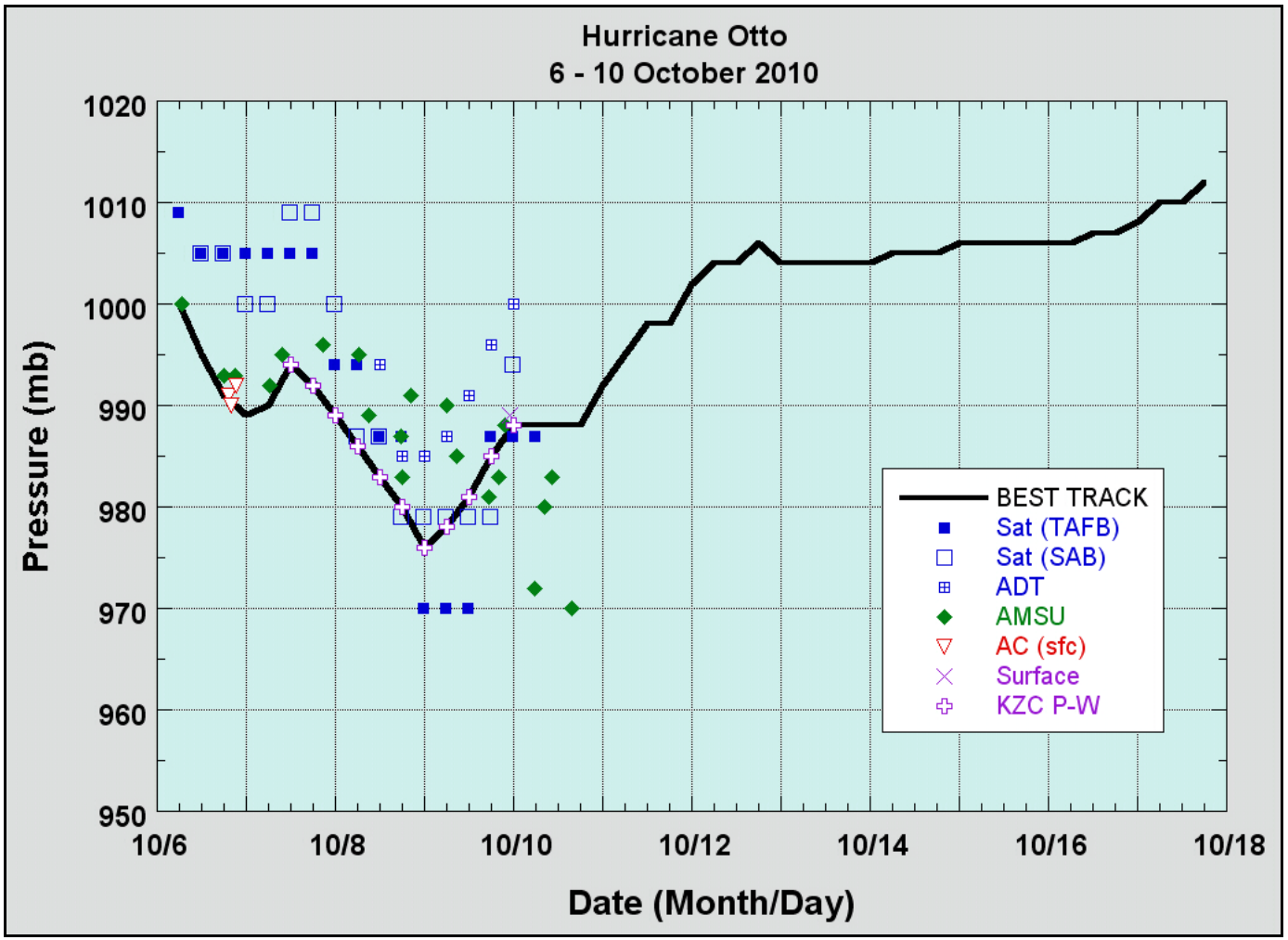

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Otto, 6-10 October 2010. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. Estimates during the extratropical stage are based on analyses from the NOAA Ocean Prediction Center. Dashed vertical lines correspond to 0000 UTC.

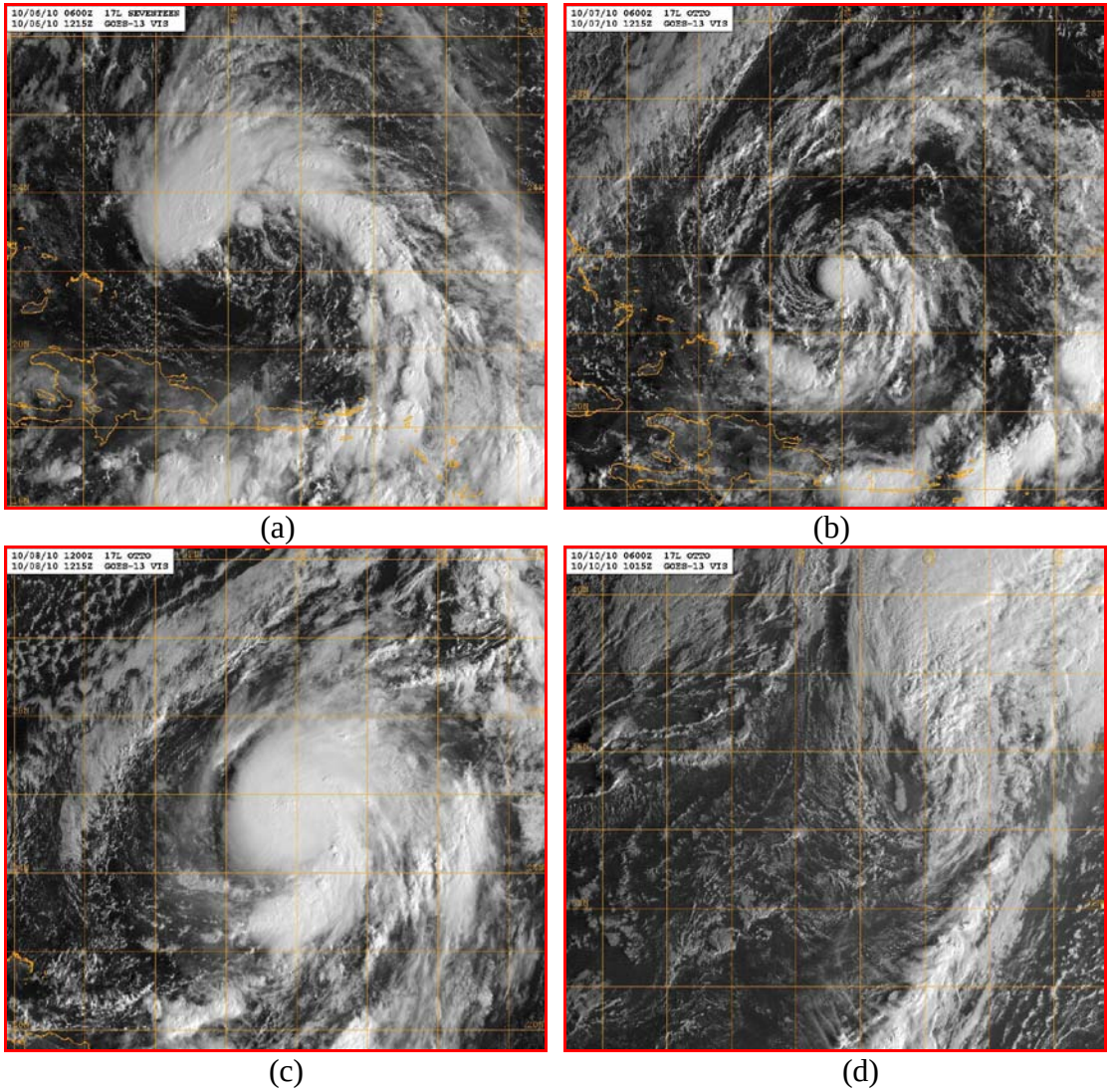

Figure 4. Visible satellite images of Otto, 6-10 October 2010, as a subtropical storm (a) at 1215 UTC 6 October, a tropical storm (b) at 1215 UTC 7 October, a hurricane (c) at 1215 8 October, and an extratropical storm (d) at 1015 UTC 10 October. Images courtesy of the United States Naval Research Laboratory.

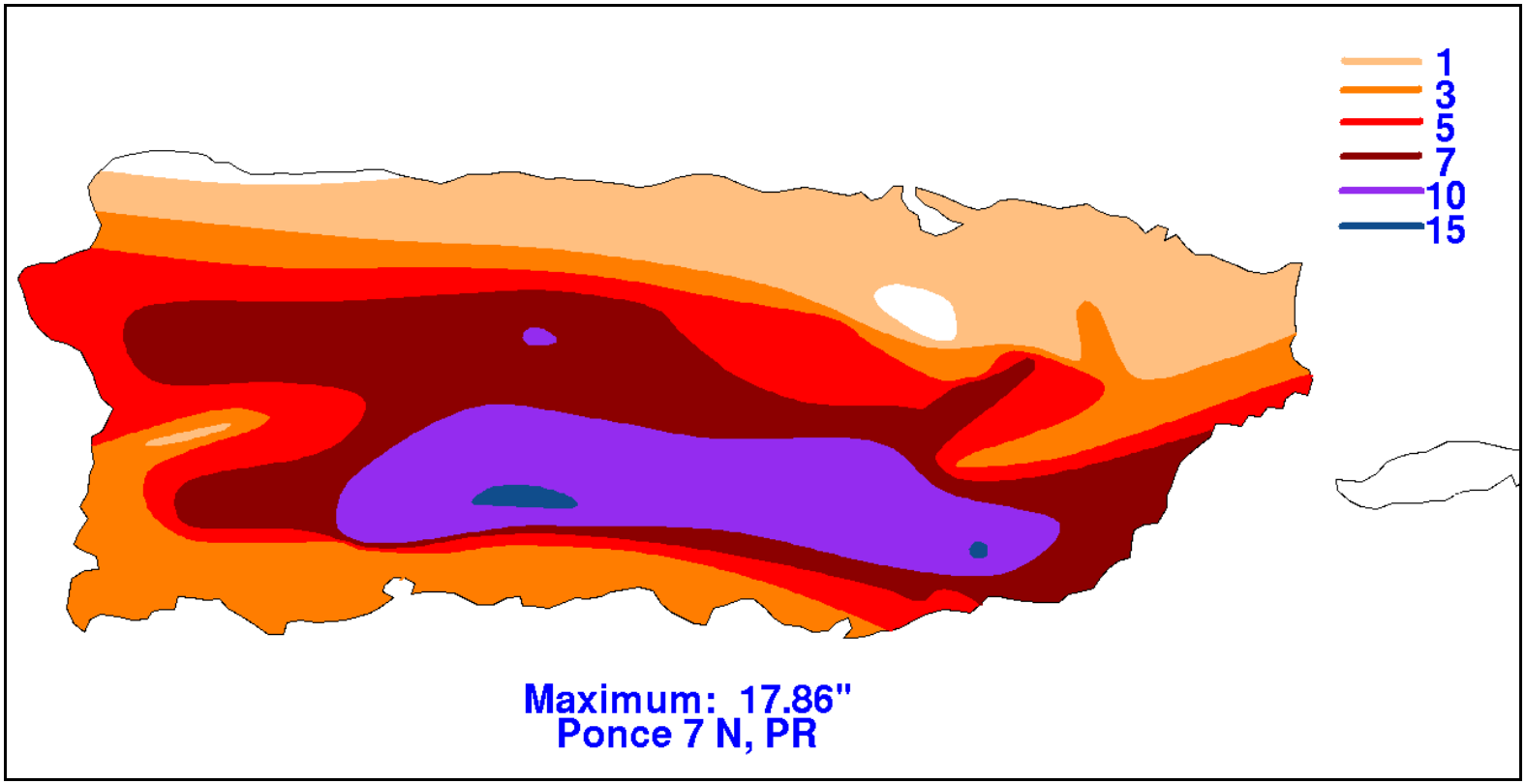

Figure 5. Accumulated rainfall map of Puerto Rico for Hurricane Otto, 6-10 October 2010, and its precursor disturbance. Figure courtesy of David Roth of the Hydrometeorological Prediction Center.