Tropical Cyclone Report
Tropical Storm Matthew
(AL152010)
23–26 September 2010

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Updated 4 January 2011 for additional rainfall data and rainfall analysis graphic for Mexico.
Updated 11 March 2011 for casualty information from Mexico and Honduras.

Matthew was a tropical storm that formed in the central Caribbean Sea and made landfall in extreme northern Nicaragua, moved across northern Honduras and made a final landfall in Belize. Matthew produced heavy rainfall across portions of northern Central America and eastern Mexico.

a. Synoptic History

Matthew had its origins in a tropical wave that left the west coast of Africa on 11 September. The wave moved westward and was associated with the genesis of Tropical Storm Julia on 12 September. The southern portion of the wave subsequently moved westward across the Atlantic with little development until convection increased east of the Windward Islands on 20 September. The wave produced rain and gusty winds as it moved across the islands that day. On 21 September the wave entered the eastern Caribbean Sea and a surface low formed along the wave axis early on 22 September. Deep convection associated with the low remained disorganized until around 0300 UTC 23 September, when shower and thunderstorm activity began to increase, and curved bands developed over the next several hours. By 1200 UTC that day it is estimated that a tropical depression formed, centered about 490 n mi east of Cabo Gracias a Dios on the Nicaragua/Honduras border. Aircraft data indicated that the depression reached tropical storm strength 6 h later while centered about 410 n mi east of Cabo Gracias a Dios. The "best track" chart of Matthew's track 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].

For most of its lifetime, Matthew was steered westward or west-northwestward at 15 to 20 kt by a subtropical ridge to its north. Matthew gradually strengthened and reached a peak intensity of 50 kt around 1800 UTC 24 September. The cyclone made landfall about an hour later in extreme northern Nicaragua about 20 n mi south of Cabo Gracias a Dios. After landfall, Matthew moved west-northwestward across northern Honduras, but the cyclone did not weaken in the first 6 h after landfall, as 50-kt surface winds were observed by aircraft off the northern coast of Honduras around 0000 UTC 25 September. Matthew began to gradually weaken after

[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.

that time, and the weakening continued as the center moved into the Gulf of Honduras shortly after 0600 UTC that day. Matthew made landfall as a minimal tropical storm around 1500 UTC 25 September about 10 n mi north-northeast of Monkey River Town, Belize. The cyclone weakened to a tropical depression around 1800 UTC as it moved inland across Belize and into northern Guatemala. By 0000 UTC 26 September, the forward speed of Matthew decreased as the center moved into Mexico. Matthew's forward speed decreased further as the cyclone became a remnant low around 1200 UTC that day. The surface circulation turned toward the southwest and dissipated shortly after 1800 UTC 26 September. Even after the surface low dissipated, heavy rainfall continued over portions of central and eastern Mexico for the next couple of days.

b. Meteorological Statistics

Observations in Matthew (Figs. 2 and 3) include subjective 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 three flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU) instrument, NASA's Tropical Rainfall Measuring Mission (TRMM), the European Space Agency's 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 Matthew.

The estimated peak intensity of Matthew is based on a peak 850-mb flight level wind of 58 kt and a peak SFMR wind speed of 51 kt that were both observed around 0000 UTC 25 September just offshore of the northern coast of Honduras.

There were no ship reports of tropical-storm-force winds in association with Matthew. Selected surface observations from land stations and data buoys are given in Table 2. The only sustained tropical-storm-force winds reported on land occurred at Puerto Lempira in northeastern Honduras, where 10-min average winds of 40 kt and 38 kt were observed at 2300 UTC 24 September and 0000 UTC 25 September, respectively. The lowest pressure observed on land was 999.6 mb on the island of Roatan at 0935 UTC on 25 September.

The main impact from Matthew was heavy rainfall across Nicaragua, Honduras, Belize, Guatemala, El Salvador, and portions of eastern and central Mexico. A rainfall analysis provided by the National Meteorological Service of Honduras (not shown) indicates that 4–8 inches (100–200 mm) of rain occurred from 24-26 September in that country. The highest rainfall totals were observed along the northwestern coast of that country and along the southern border with El Salvador and Nicaragua. Point rainfall maxima from Honduras and Guatemala (Table 2) were in the 5–7 inches (127–178 mm) range. The highest rainfall total in Mexico was the 16.73 inches (425 mm) observed at Acayucan in the state of Veracruz (Table 2, Figure 4). Rainfall totals of 5–10 inches (245–590 mm) were observed across portions of several Mexican states, including Veracruz, Chiapas, and Oaxaca.

c. Casualty and Damage Statistics

According to media reports, there were a total of 78 fatalities associated with Matthew. Sixty-five of these deaths occurred in Nicaragua and four occurred in Honduras. In Mexico eight fatalities were reported. One man drowned in El Salvador, and another man was reported missing.

No monetary damage estimates are available. In Guatemala, however, over 1,000 homes were reported damaged in Guatemala. In Honduras, 172 homes were damaged, several bridges and roads were damaged or destroyed, and rice, banana, and sugarcane crops were ruined. In Nicaragua, corn and bean harvests were also affected. Approximately 15,000 people in Nicaragua, Guatemala, and Honduras were evacuated because of the storm.

Heavy rainfall associated with the remnants of Matthew was partly responsible for a landslide in Santa Maria Tlahuitoltepec in the Mexican state of Oaxaca on 28 September; however, rainfall not associated with Matthew had also affected this area in previous days. Four people were killed and 12 people were missing because of the landslide according to media reports. Two homes were destroyed and about 30 homes were damaged.

d. Forecast and Warning Critique

The genesis of Matthew was well anticipated. The tropical wave associated with the development of Matthew was first mentioned in the Tropical Weather Outlook 54 h prior to genesis and given a low (< 30%) chance of formation in the next 48 h. The genesis probability was raised to the medium (30-50%) category 12 h later and then raised to the high category (> 50%) 24 h prior to genesis.

A verification of NHC official track forecasts (OFCL) for Matthew is given in Table 3a. Official forecast track errors were much higher than the mean official errors for the previous five-year period (2005–2009). However, CLIPER model errors (OCD5) for Matthew were near the 2005–2009 average values at all time periods, suggesting that Matthew's track forecasts were of average difficulty. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. The TVCN multi-model consensus and the GFS (GFSI) and NOGAPS (NGPI) models beat the official forecast at all time periods, although the sample size was small at 48 h. Interestingly, the smallest average track forecast errors came from the relatively simple LBAR model, which had average errors 50–80% smaller than OFCL. An examination of OFCL and dynamical model track forecasts (not shown) reveals a sizeable slow bias in predicting the forward speed of Matthew throughout its lifetime.

A verification of NHC official intensity forecasts (OFCL) for Matthew is given in Table 4a. Official forecast intensity errors were lower than the mean official errors for the 2005–2009 period through 36 h. Errors for the Decay-SHIFOR model (OCD5) were smaller than the 2005–2009 average, suggesting that Matthew's intensity was easier to forecast than that of a typical system. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. The GFDL and HWRF models (GHMI and HWFI,

respectively) had smaller average errors than OFCL at time periods beyond 12 and 24 h, respectively. The intensity consensus models (ICON and IVCN) also beat OFCL at lead times of 24 h and beyond. This occurred despite the relatively poor performance of the statistical DSHP and LGEM models, which had a sizeable high bias at 36 and 48 h, in part due to early official forecasts track keeping the center of Matthew offshore too long.

Coastal watches and warnings associated with Matthew are listed in Table 5. The tropical storm warning from Puerto Cabezas, Nicaragua, to Limon, Honduras, including the offshore islands, was issued about 23 h prior to Matthew's landfall near the Nicaragua/Honduras border. The tropical storm warning from Belize City southward to the Belize/Guatemala border was issued about 12 h prior to Matthew's landfall in Belize. Hurricane watches were issued for portions of Nicaragua, Honduras, and Belize, as early official forecasts showed Matthew reaching hurricane intensity prior to landfall.

Acknowledgements

Data from the island of Roatan were provided by Dr. John Braun from the COSMIC program at the University Corporation for Atmospheric Research. Servicio Meteorológico Nacional of Mexico provided some of the rainfall data in Table 2 and used for the analysis in Figure 4.

Table 1. Best track for Tropical Storm Matthew, 23–26 September 2010.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
23 / 1200	13.7	74.8	1008	30	tropical depression
23 / 1800	13.9	76.2	1007	35	tropical storm
24 / 0000	14.0	77.7	1005	40	"
24 / 0600	14.0	79.3	1003	45	"
24 / 1200	14.2	81.1	1001	45	"
24 / 1800	14.6	83.0	998	50	"
24 / 1900	14.7	83.3	998	50	"
25 / 0000	15.2	84.6	998	50	"
25 / 0600	15.8	86.1	998	45	"
25 / 1200	16.3	87.7	1000	35	"
25 / 1500	16.5	88.4	1000	35	"
25 / 1800	16.7	89.4	1000	30	tropical depression
26 / 0000	17.0	90.8	1001	30	"
26 / 0600	17.3	91.9	1002	25	"
26 / 1200	17.5	92.8	1002	20	low
26 / 1800	17.2	93.3	1003	20	"
27 / 0000					dissipated
24 / 1800	14.6	83.0	998	50	minimum pressure and maximum wind
24 / 1900	14.7	83.3	998	50	landfall in northern Nicaragua about 20 n mi south of Cabo Gracias a Dios on the Nicaragua/Honduras border
25 / 1500	16.5	88.4	1000	35	landfall about 10 n mi north-northeast of Monkey River Town, Belize

Table 2. Selected surface observations for Tropical Storm Matthew, 23–26 September 2010.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)	Storm tide (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Nicaragua								
Puerto Cabezas (MNPC)	24/2200	1003.1	24/1900	20				
Honduras								
Puerto Lempira (MHPL)	24/2300	1007.1	24/2300	40				1.62
Roatan	25/0930	999.6	25/1055	20				0.51
La Ceiba (MHLC)	25/1000	1001.0	25/0700	10				5.04
Tela (MHTE)								7.28
Yoro (MHYR)								2.20
La Mesa San Pedro Sula (MHLM)								1.73
Catacamas (MHCA)								1.69
Santa Rosa de Copan (MHSR)								1.22
Guatemala								
Tikal (MGTK)	25/2100	1001.0						
Puerto Barrios (MGPB)	25/2000	1003.1	25/1700	18				6.42
Flores (MGFL)								6.10
Huehuetenango (MGHT)								1.46
Belize								
Belize City – Philip Goldston Int'l Airport (MZBZ)	25/2000	1003.7	25/1600	16	26			1.02
Mexico								
Ciudad del Carmen (MMCE)	25/2200	1004.1	26/0000	25				
Acayucan								19.61
Ocotepec								13.52
Coatzacoalcos								13.15
Alvarado								12.59
La Cangrejera								12.21
Matias Romero								11.35
Tres Picos								10.13

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)	Storm tide (ft)	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)			
Predon								9.04
Arriaga (76840)								8.90
F. La Paz								8.56
Bonampak								7.94
Punto Chiapas								7.68
Tuxtla (76743)								5.51
Guanajuato (MMTG)								5.16
Puerto Ventura								4.85
San Cristobal (76845)								4.09
Comitan (76848)								3.79
Tapachula (76903)								3.66
Veracruz (76692)								2.71
Oaxaca (76775)								1.38

Buoys								
NOAA Buoy 42057 Western Caribbean (16.83°N 81.50°W)	24/2027	1007.0	24/1547	39	45			

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Averaging period is 10 min for land stations and 1 min for buoys.

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Matthew. 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 (Matthew)	54.9	94.0	129.2	201.8			
OCD5 (Matthew)	54.9	102.3	148.6	221.6			
Forecasts	10	8	6	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 Tropical Storm Matthew. 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	57.3	92.9	130.7	199.3			
GFSI	**56.0**	**76.5**	**100.8**	**137.3**			
GHMI	81.0	142.4	200.9	208.8			
HWFI	**56.7**	107.9	173.9	244.2			
NGPI	**55.4**	**87.2**	**121.7**	**168.4**			
NAMI	75.3	122.8	179.3	254.8			
AEMI	67.7	123.6	189.1	254.1			
TVCN	**54.8**	**87.9**	**123.8**	**162.7**			
TVCC	61.1	100.3	143.2	**184.9**			
LBAR	**43.9**	**46.1**	**37.0**	**47.0**			
BAMD	**51.0**	**82.6**	**128.8**	**180.4**			
BAMM	**54.0**	**85.3**	**122.9**	**154.9**			
BAMS	74.0	122.6	162.3	**184.8**			
Forecasts	9	6	5	3			

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Matthew. 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 (Matthew)	**5.5**	**5.6**	**10.0**	31.3			
OCD5 (Matthew)	6.8	5.3	5.7	18.0			
Forecasts	10	8	6	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 Tropical Storm Matthew. 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	5.5	5.6	10.0	31.3			
GHMI	6.1	**4.8**	**8.0**	**15.5**			
HWFI	7.3	10.3	**8.5**	**4.0**			
DSHP	6.9	6.9	12.5	32.3			
LGEM	6.5	8.8	12.3	34.0			
ICON	6.0	**5.5**	**8.5**	**20.8**			
IVCN	5.8	**5.0**	**6.8**	**17.8**			
Forecasts	10	8	6	4			

Table 5. Watch and warning summary for Tropical Storm Matthew, 23–26 September 2010.

Date/Time (UTC)	Action	Location
23/1800	Tropical Storm Warning and Hurricane Watch issued	Puerto Cabezas, Nicaragua, to Limon, Honduras, including the offshore islands
24/0300	Tropical Storm Warning changed to Hurricane Warning	Puerto Cabezas, Nicaragua, to Limon, Honduras, including the offshore islands
24/0300	Tropical Storm Warning issued	West of Limon, Honduras, to the Honduras/Guatemala border
24/0600	Hurricane Watch issued	Belize/Mexico border to Belize/Guatemala border
24/1500	Hurricane Warning changed to Tropical Storm Warning and Hurricane Watch	Puerto Cabezas, Nicaragua, to Limon, Honduras, including the offshore islands
24/1500	Hurricane Watch changed to Tropical Storm Watch	Belize/Mexico border to Belize/Guatemala border
24/2100	Hurricane Watch discontinued	Puerto Cabezas, Nicaragua, to Limon, Honduras, including the offshore islands
25/0300	Tropical Storm Warning issued	Belize City south to Belize/Guatemala border
25/0300	Tropical Storm Warning discontinued	Puerto Cabezas, Nicaragua, to Nicaragua/Honduras border, including the offshore islands
25/1500	Tropical Storm Warning discontinued	East of Punta Sal, Honduras
25/1800	All coastal watches and warnings discontinued	

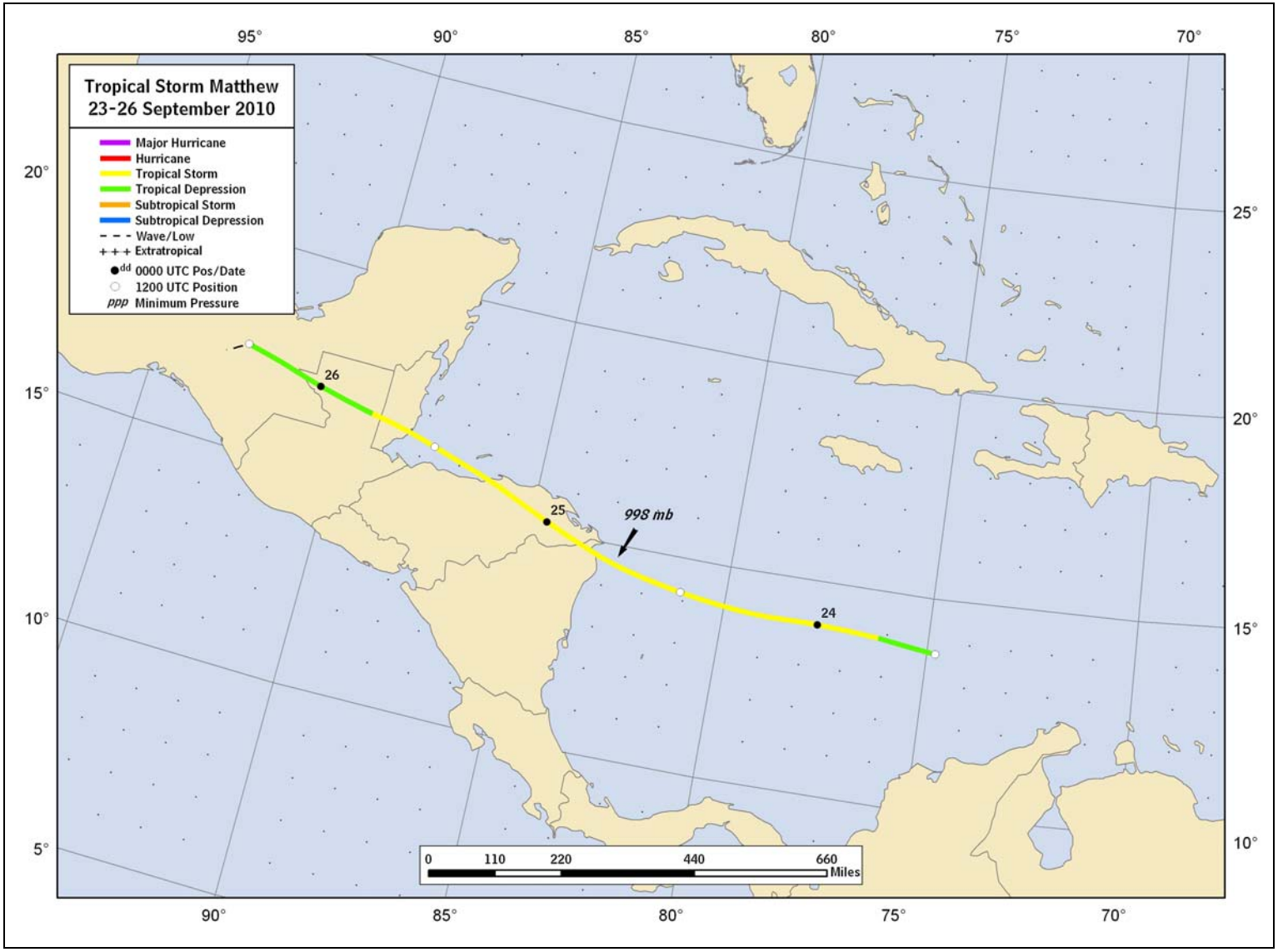

Figure 1. Best track positions for Tropical Storm Matthew, 23–26 September 2010.

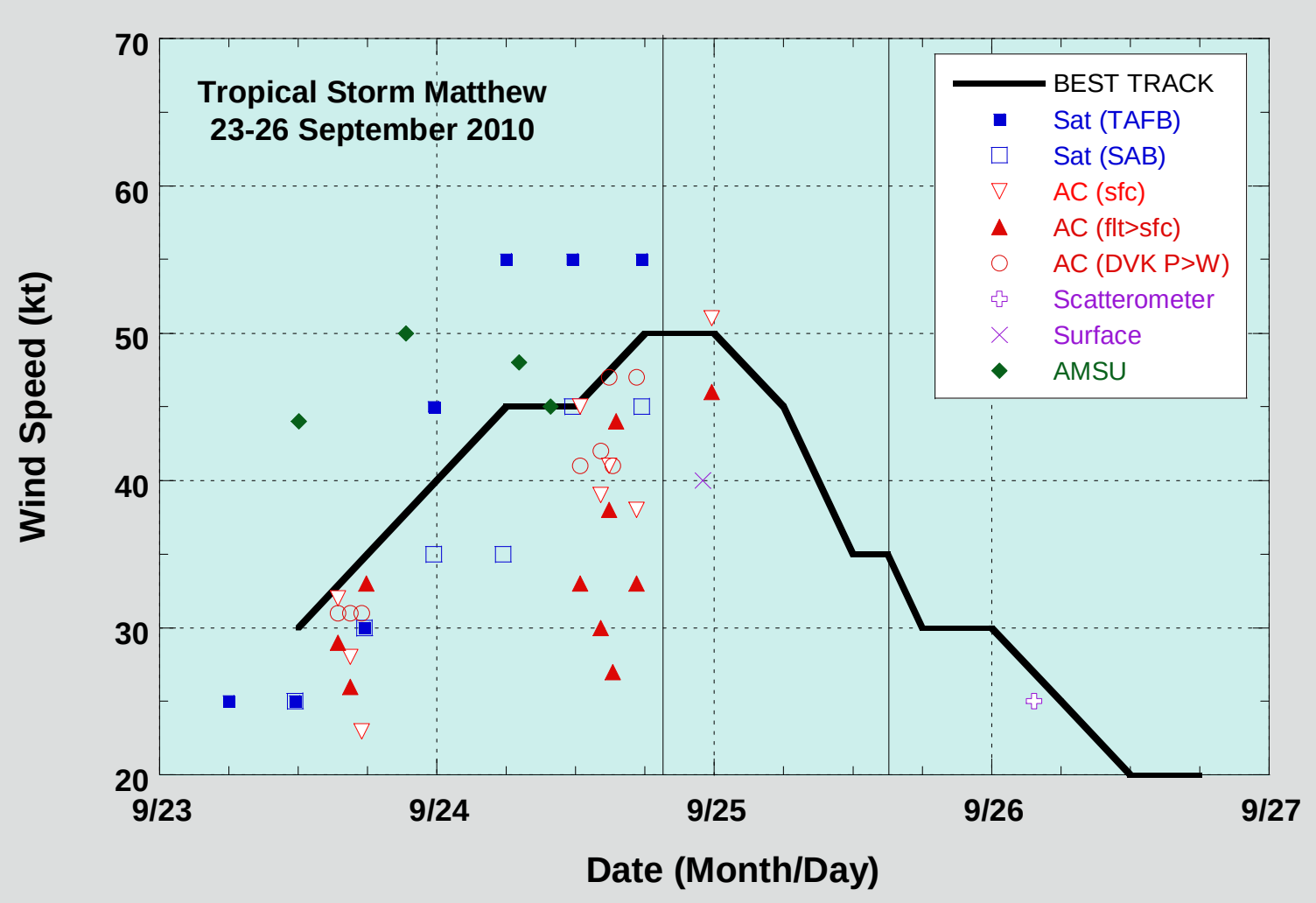

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Matthew, 23–26 September 2010. Dashed vertical lines correspond to 0000 UTC. Solid vertical lines correspond to landfalls. AMSU data are from the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin intensity technique.

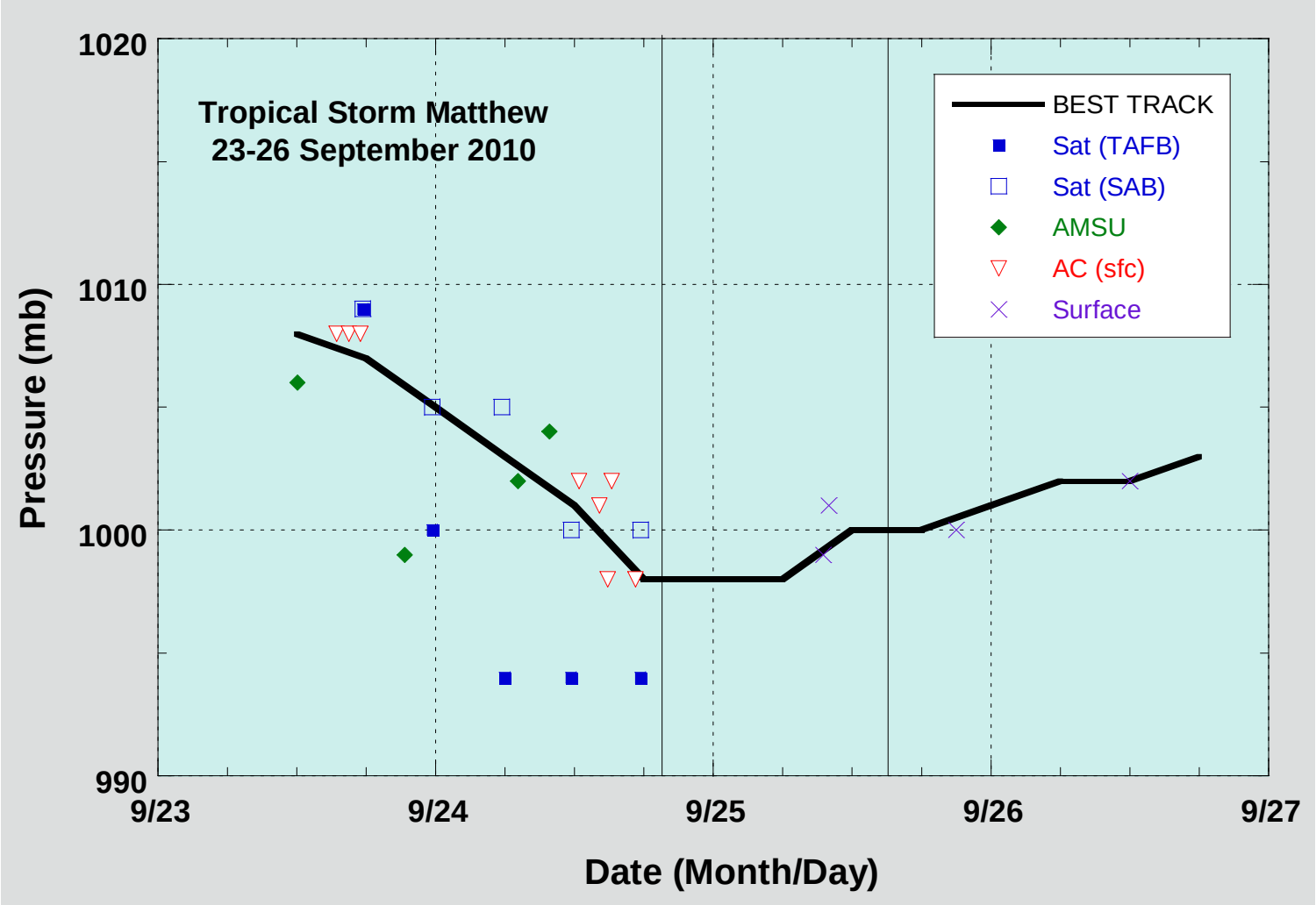

Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Matthew, 23–26 September 2010. Dashed vertical lines correspond to 0000 UTC. Solid vertical lines correspond to landfalls. AMSU data are from the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin intensity technique.

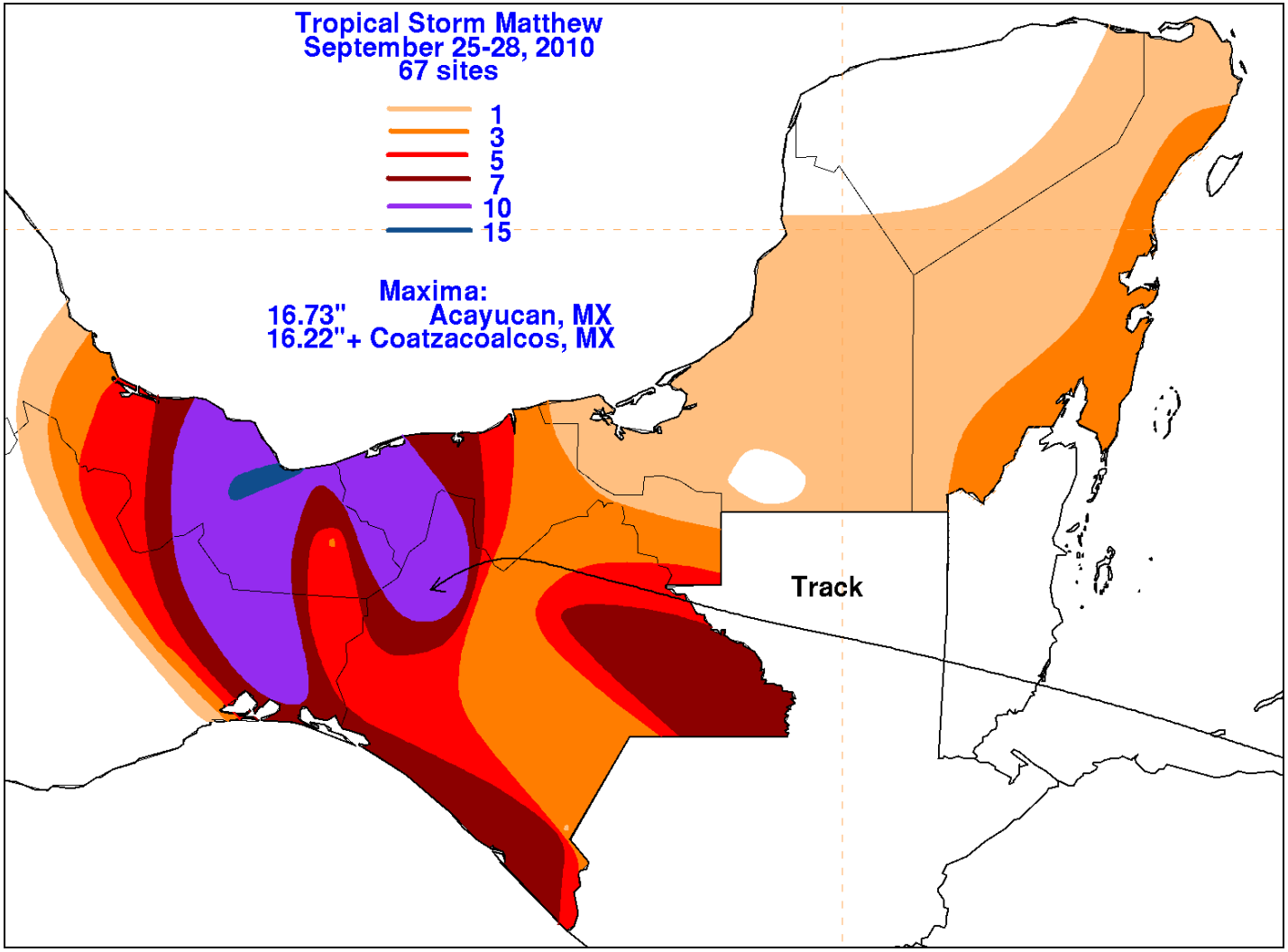

Figure 4. Rainfall totals (in.) associated with Tropical Storm Matthew and its remnants over Mexico. Image courtesy of David Roth of the NWS Hydrometeorological Prediction Center in Camp Springs, MD.