Tropical Cyclone Report
Hurricane Maria
(AL142011)
6-16 September 2011

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Maria formed in the eastern Atlantic Ocean and brought tropical storm conditions to portions of the Lesser Antilles. Maria then became a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) as it recurved through the northwestern Atlantic before it made landfall in Newfoundland as a strong tropical storm.

a. Synoptic History

Maria originated from a tropical wave that moved across the west coast of Africa on 2 September. The wave moved westward well to the south of the Cape Verde islands on 3-4 September with little in the way of organized deep convection. Thunderstorm activity increased markedly early on 5 September but remained displaced to the west of the broad surface circulation due to strong easterly vertical wind shear. On 6 September, the low-level center became better defined and deep convection increased further and a tropical depression formed by 1800 UTC that day, centered about 700 n mi west-southwest of the southern Cape Verde Islands. The cyclone moved quickly west-northwestward at 15 to 20 kt and reached tropical storm intensity 6 h later, while centered about 790 n mi west-southwest of the southern Cape Verde Islands. The "best track" chart of Maria'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].

Maria moved quickly west-northwestward to the south of a subtropical ridge on 7 September and reached an intensity of 45 kt around 1200 UTC that day. However, by early the next day southwesterly vertical wind shear increased over the cyclone, and the deep convection became displaced to the northeast of the fast-moving low-level center. By early on 9 September, the forward speed of Maria slowed to around 15 kt as the storm turned west-northwestward, and deep convection began to redevelop closer to the low-level circulation. However, data from an Air Force Reserve Hurricane Hunter aircraft mission into Maria later that day indicated that the low-level circulation lost definition, even as the system was producing maximum sustained winds of around 45 kt mainly to the northeast of the center. Based on the aircraft data, satellite imagery, and surface observations, it is estimated that Maria no longer had a well-defined center and dissipated as a tropical cyclone around 1200 UTC 9 September.

[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.

The remnants of Maria, accompanied by a strong mid-level circulation, turned northwestward and approached the Lesser Antilles by late on 9 September. Satellite imagery and surface and aircraft observations indicate that a new center developed around 1200 UTC 10 September about 40 n mi east-southeast of Antigua, and Maria again became a tropical storm at that time. Maria continued to experience strong westerly vertical wind shear while it moved northwestward and then west-northwestward, and its forward motion slowed as the center passed to the north of the Virgin Islands and Puerto Rico the next day.

The forward speed of Maria slowed considerably on 12 September when the cyclone reached the southwestern periphery of the subtropical ridge. Maria then turned northwestward while its forward speed increased to around 10 kt by 0000 UTC 14 September. Vertical wind shear relaxed somewhat during the next day or so and Maria began to be steered by a deep-layer trough moving off of the east coast of North America. The cyclone slowly strengthened on 14 September as deep convection became more concentrated near the center. Maria turned northward by 15 September and continued strengthening, reaching hurricane intensity around 1800 UTC that day while centered about 135 n mi northwest of Bermuda (Fig. 4). On 16 September, Maria became embedded in the mid-latitude flow and accelerated northeastward, reaching an estimated peak intensity of 70 kt at 0000 UTC that day, before weakening due to cooler waters and increased vertical wind shear. Maria was a 60-kt tropical storm when the center made landfall around 1830 UTC 16 September near Cape St. Mary's on the Avalon Peninsula of Newfoundland, Canada. The cyclone's circulation was absorbed by a frontal system shortly thereafter.

b. Meteorological Statistics

Observations in Maria (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), and objective Advanced Dvorak Technique (ADT) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from six 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, the NASA Tropical Rainfall Measuring Mission (TRMM) and Aqua, the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Maria.

Ship and fixed platform reports of winds of tropical storm force associated with Maria are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

As Maria and its remnants passed near and north of the Leeward Islands and the Virgin Islands on 9-11 September, the strongest observed sustained wind was 45 kt at La Desirade, located just to the east of Guadeloupe. Tropical-storm-force wind gusts were observed on Antigua, Guadeloupe, Marie-Galante, Barbuda, St. Maarten/St. Martin, St. Croix, and St.

Thomas, but sustained winds remained below tropical storm force. In several of these locations, the strongest winds occurred before Maria regenerated into a tropical cyclone.

Widespread rainfall totals of 5 to 11 inches were observed in Puerto Rico (Fig. 5), with a maximum of 11.60 inches at Aibonito. Rainfall totals in the Leeward Islands were generally 1 to 2 inches.

Maria produced storm surge values of 0.50 to 0.75 ft in Barbuda, St. Croix, St. John, Vieques, Mona Island, and Puerto Rico. The highest observed storm tide was 2.03 ft above Mean Lower Low Water at Arecibo on the northern coast of Puerto Rico.

As Maria passed west of Bermuda on 15 September, sustained winds of 34 kt were reported at L.F. Wade International airport, along with a peak wind gust of 43 kt.

Maria's analyzed peak intensity of 70 kt is based on a blend of subjective Dvorak intensity estimates of 77 kt from TAFB and 65 kt from SAB and a 3-h average ADT intensity estimate of 72 kt from UW-CIMSS at 0600 UTC 16 September. The estimated minimum central pressure of 983 mb is based on an observed pressure of 985.4 mb with 25-kt winds at Environment Canada buoy 44141 around 1200 UTC 16 September.

Maria made landfall in Newfoundland around 1830 UTC 16 September on the Avalon Peninsula near Cape St. Mary's as a strong tropical storm with maximum sustained wind of 60 kt. The estimated landfall intensity is based on subjective Dvorak intensity estimates of 55 kt from TAFB and SAB at 1800 UTC and a 10-min wind of 52 kt from Environment Canada buoy 44138 at 1520 UTC, which suggests a peak 1-min wind of 57 kt when applying an adjustment factor of 1.11 (Harper et al. 2009). The analyzed minimum central pressure of 983 mb at landfall is based on an observed pressure at Grate's Cove of 983.9 mb, which occurred with 16 kt of wind. The strongest winds associated with Maria remained offshore to the southeast of Newfoundland, though sustained tropical-storm-force winds were observed at Cape Race, Bonavista, and Sagona Island, with wind gusts above 50 kt observed at all of those locations as well as at St. Lawrence. Rainfall amounts in the Burin Peninsula and the south coast of Newfoundland were around 2.35 inches (60 mm), with a total of 2.48 inches (63 mm) observed at St. Lawrence.

c. Casualty and Damage Statistics

There were no reports of casualties associated with Maria.

In Puerto Rico numerous roads were flooded due to rainfall and 20 homes were flooded in Cabo Rojo. Thirty families were moved to shelters after their homes were flooded in Ceiba, Juana Diaz, and Barranquitas. A total of 15,700 people lost power in Puerto Rico due to the storm. No monetary damage estimates are available.

No other reports of damage or impacts were received.

d. Forecast and Warning Critique

The genesis of Maria was not well anticipated. The precursor system that developed into Maria was not introduced into the Tropical Weather Outlook until 30 h before genesis, when it was given a low (< 30%) chance of development. However, the genesis probability was raised to the high category (> 50% chance of development) 6 h later and remained in that category until genesis occurred.

A verification of NHC official track forecasts for Maria is given in Table 4a. Official forecast track errors (OFCL) were generally 20% to 25% larger than the mean official errors for the previous 5-yr period, except at 72 h when the average error was only about 10% above the mean 5-yr value. Errors from the CLIPER climatology-persistence baseline model (OCD5) were higher than the previous 5-yr mean through 72 h, suggesting that the track of Maria was somewhat more difficult to forecast than average through 3 days. A homogeneous comparison of the OFCL track errors with selected guidance models is given in Table 4b. The TCON, TVCA, TVCE, and TVCC consensus models beat OFCL at all time periods. The best-performing individual model was the GFS (GFSI), which had smaller errors than OFCL through 72 h. The GFDN model (GFNI) had the smallest errors of any single model at days 4 and 5. The largest OFCL errors occurred for forecasts made on 8-9 September. At these times OFCL and the TVCA consensus model both showed Maria moving to the left of the observed track through the Lesser Antilles and closer to Puerto Rico before reaching a 5-day position east of the central Bahamas (Fig. 6). These errors appear to be due in part to difficulty analyzing the initial position of Maria prior to its dissipation at 1200 UTC 9 September, as the initial position and short term forecasts were south of the observed track.

A verification of NHC official intensity forecasts for Maria is given in Table 5a. Official forecast intensity errors (OFCL) were 40% to 60% lower than the mean official errors for the previous 5-yr period at all lead times. Average errors from the SHIFOR5 climatology-persistence baseline model (OCD5) were also lower than the previous 5-yr mean, suggesting that the intensity of Maria was somewhat easier to forecast than average. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. The official forecast had smaller average errors than all of the model guidance, except for the LGEM at 48 and 72 h. The regional hurricane models, the GFDL (GHMI), the U.S. Navy version of the GFDL (GFNI), and the HWRF (HWFI), all had large positive intensity biases for Maria (Fig. 7). In particular, from 10-12 September the GHMI and GFNI repeatedly forecast Maria to strengthen to near-major or major hurricane intensity despite the notably sheared environment in which the cyclone was embedded. While the official forecast also had a small positive intensity bias, OFCL forecasts issued on 10-12 September correctly predicted that Maria would not become stronger than a category 1 hurricane.

Watches and warnings associated with Maria are given in Table 6.

Acknowledgements

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References

Harper, B.A., J.D. Kepert, and J.D. Ginger, 2009: *Guidelines for Converting Between Various Wind Averaging Periods in Tropical Cyclone Conditions.* World Meteorological Organization, 52 pp.

Table 1. Best track for Hurricane Maria, 6–16 September 2011.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
06 / 1800	11.5	35.9	1008	30	tropical depression
07 / 0000	11.9	37.5	1007	35	tropical storm
07 / 0600	12.3	39.1	1006	40	"
07 / 1200	12.8	41.0	1004	45	"
07 / 1800	13.0	43.0	1004	45	"
08 / 0000	13.2	45.2	1003	45	"
08 / 0600	13.2	47.7	1002	45	"
08 / 1200	13.0	50.1	1004	40	"
08 / 1800	13.2	52.1	1004	40	"
09 / 0000	13.5	53.7	1004	40	"
09 / 0600	13.9	55.2	1003	40	"
09 / 1200	14.3	56.6	1003	45	disturbance
09 / 1800	14.9	57.9	1004	45	"
10 / 0000	15.4	59.0	1004	45	"
10 / 0600	16.0	60.0	1005	45	"
10 / 1200	16.9	61.1	1005	45	tropical storm
10 / 1800	17.8	62.0	1005	45	"
11 / 0000	18.3	62.7	1005	45	"
11 / 0600	18.7	63.4	1004	50	"
11 / 1200	19.1	64.1	1004	50	"
11 / 1800	19.6	64.7	1005	50	"
12 / 0000	20.0	65.3	1005	50	"
12 / 0600	20.4	66.1	1005	50	"
12 / 1200	20.6	66.9	1006	50	"
12 / 1800	20.8	67.1	1006	50	"
13 / 0000	21.0	67.3	1006	45	"
13 / 0600	21.3	67.5	1006	45	"
13 / 1200	21.7	67.7	1006	45	"
13 / 1800	22.3	68.0	1005	45	"
14 / 0000	23.1	68.5	1004	45	"
14 / 0600	23.9	69.0	1001	50	"
14 / 1200	24.7	69.3	1001	50	"
14 / 1800	25.8	69.3	1000	55	"
15 / 0000	27.2	68.9	999	60	"
15 / 0600	28.8	68.4	995	60	"
15 / 1200	30.9	67.8	991	60	"
15 / 1800	33.7	66.9	987	65	hurricane

16 / 0000	36.8	64.8	984	70	"
16 / 0600	39.8	62.1	983	70	"
16 / 1200	42.9	58.2	983	65	"
16 / 1800	46.7	53.9	983	60	tropical storm
16 / 2100					dissipated
16 / 1830	47.0	53.5	983	60	Landfall near Cape St. Mary's, Newfoundland, Canada
16 / 0600	39.8	62.1	983	70	minimum pressure

Table 2. Selected ship and fixed platform reports with winds of at least 34 kt for Hurricane Maria and its remnants, 6–16 September 2011.

Date/Time (UTC)	Ship/Platform call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
13 / 0000	DEDI	21.7	64.2	140 / 40	1015.0
13 / 1200	A8IN8	21.0	62.7	020 / 35	1014.0
14 / 0000	VRXL7	24.8	64.6	170 / 38	1015.5
14 / 1200	A8SE8	23.6	62.6	130 / 35	1016.5
16 / 0300	WPGK	37.7	72.7	340 / 40	1012.3
16 / 0300	NWS002	42.2	69.8	320 / 37	1011.3
16 / 0700	ZCDG8	40.5	69.3	330 / 50	1012.3
16 / 1300	VRGT8	41.9	65.5	320 / 36	1012.0
16 / 1400	WKAP	43.3	63.4	310 / 35	1012.9
16 / 1500	YJUF7	46.7	48.0	170 / 41	1015.4
16 / 1800	VCXF	46.4	48.4	160 / 43	1008.8
16 / 1800	VEP717[a]	46.7	48.7	160 / 58	1009.1
16 / 1800	YJUF7	46.7	48.0	170 / 44	1010.3
16 / 1800	VXKF	47.1	59.6	300 / 45	999.8
16 / 1800	YJQN7	48.3	46.2	180 / 38	1013.6
16 / 1900	VCRG	46.7	61.8	280 / 42	1007.8

[a] Hibernia oil platform; anemometer height is 456 ft.

Table 3. Selected surface observations for Hurricane Maria and its remnants, 6–16 September 2011.

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)			
Lesser Antilles								
International Civil Aviation Organization (ICAO) Sites								
Antigua (TAPA)	10/1830	1007.0	10/0245	20[f]	37			0.91
Guadeloupe (TFFR)	10/1600	1007.4	09/1500	26	42			1.40
Marie-Galante (TFFM)	10/0300	1006.6	09/1700	20	35			1.32
La Desirade (TFFA)	10/1800	1006.8	09/1400	45	55			0.39
Dominica (TDPD)	10/1900	1007	09/2000	22	32			
Martinique (TFFF)	09/1600	1007.7	09/0900	21	31			1.32
Nevis (TKPN)			11/1500	28	31			
St. Kitts (TKPK)	10/1900	1007	11/1300	20				
St. Maarten – Juliana Airport (TNCM)	11/0600	1006	11/1500	25	35			
St. Martin – Grand Case Airport (TFFG)	11/0200	1006.5	11/1400	21[f]	47			1.97
St. Barthelemy (TFFJ)	11/0200	1006.5	09/1600	23[f]	43			0.94
National Ocean Service (NOS) Sites								
Barbuda 17.59°N 61.82°W	10/1954	1005.1	11/0812	30	42	0.67	1.25	
United States								
U.S. Virgin Islands								
ICAO Sites								
Charlotte Amalie St. Thomas, VI (TIST)	11/0853	1008.5	12/1303	29	42			1.65
NOS Sites								
Christiansted Harbor, St. Croix, VI 17.75°N 64.71°W	11/0718	1008.1	10/2224	21	48	0.55	1.01	
Lameshur Bay, St. John, VI 18.32°N 64.72°W	11/0936	1007.9				0.59	1.15	
Charlotte Amalie, St. Thomas, VI 18.34°N 64.92°W	11/0754	1007.5				0.41	1.18	

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)			
Lime Tree Bay, St. Croix, VI 17.69°N 64.75°W	11/0712	1008.1	12/1618	27	33	0.25	0.97	
Puerto Rico								
ICAO Sites								
Roosevelt Roads, PR (TJNR)								9.48
NOS Sites								
Culebra, PR 18.30°N 65.30°W	11/0718	1010.5	13/0236	26	33	0.59	1.45	
Isabel Segunada, Vieques Island, PR 18.15°N 66.44°W			12/1606	17	28	0.30	1.53	
Esperanza, Vieques Island, PR 18.09°N 65.47°W	11/0718	1009.5	12/2036	24	28	0.66	1.01	
Fajardo, PR 18.34°N 65.63°W	11/1848	1010.4	11/0500	24	30	0.32	1.83	
Yabucoa Harbor, PR 18.06°N 65.83°W			13/0724	15	22	0.57	1.02	
San Juan, PR 18.46°N 66.12°W	12/2000	1009.8	08/2106	22	29	0.31	1.73	
Arecibo, PR 18.48°N 66.70°W	12/2006	1013.0	12/2012	18	24	0.73	2.03	
Magueyes Island, PR 17.97°N 67.05°W	11/1924	1010.0	13/0706	21	27	0.26	0.98	
Mayaguez, PR 18.22°N 67.16°W	11/1930	1014.1	13/1200	16	30	0.62	1.58	
Aguadilla, PR 18.46°N 67.16°W	14/0854	1011.7				0.48	1.48	
Mona Island, PR 18.09°N 67.94°W						0.55	1.08	
Public/Other								
Aibonito, PR (AIBP4) 18.14°N 66.27°W								11.60
Yabucoa, PR (YBUP4) 18.06°N 65.88°W								11.10
Villalba, PR (TOXP4) 18.13°N 66.48°W								9.02
Ceiba, PR (CEIBP4) 18.26°N 65.65°W								8.03
Patillas, PR (PASP4) 18.00°N 66.01°W								7.09

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)			
Luquillo, PR (MSCP4) 18.37°N 65.72°W								6.32
Coamo, PR (COAP4) 18.08°N 66.36°W								6.21
Naguabo, PR (NGHP4) 18.21°N 65.74°W								5.75
San Lorenzo (SLGP4) 18.19°N 65.97°W								5.42
Juana Diaz (JUBP4) 18.05°N 66.50°W								5.24
Bermuda								
ICAO Sites								
L.F. Wade International Airport (TXKF)	15/1555	1013	15/1531	34[f]	43			0.16
Canada								
Newfoundland								
ICAO Sites								
Sagona Island (CWZN)	16/1900	990.8	16/2040	44[f]	52			
Bonavista (CAVA)	16/2000	986.0	16/2200	40[f]	54			
Cape Race (CWRA)	16/1800	985.0	16/1800	36[f]	54			
St. Lawrence (CADS)	16/1700	990.0	16/2000	33[f]	51			2.48
Argentia (CWAR)	16/1800	987.7	16/2300	33[f]	45			
Grates's Cove (CWVW)	16/2000	983.9	16/2100	31[f]	47			
Terra Nova National Park (CXTP)	16/2000	988.1	16/2200	20[f]	38			
Burgeo (CWBD)								2.40
Nova Scotia								
ICAO Sites								
Sable Island (CWSA)	16/1200	998.0	16/1641	27[f]	33			
Buoys								
NDBC Buoy 41041 Mid-Atlantic 14.18°N 46.00°W	08/0650	1009.8	08/0126	42[e]	53			
NDBC Buoy 41040 West Atlantic 14.48°N 53.01°W	08/2245	1007.1	08/1923	35[e]	41			
NDBC Buoy 42060 Eastern Caribbean	10/2034	1007.8	11/1742	35[e]	41			

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)			
16.33°N 63.40°W								
NDBC Buoy 41043 Southwest Atlantic 21.06°N 64.97°W	11/2250	1010.6	12/0451	41[e]	45			
NDBC Buoy 41046 E Bahamas 23.84°N 68.33°W	14/0547	1004.1	14/1611	41[e]	47			
Environment Canada Buoy 44138 SW Grand Banks 44.25°N 56.63°W	16/1520	997.6	16/1520	52[f]	70			
Environment Canada Buoy 44141 Laurentian Fan 42.99°N 57.96°W	16/1120	985.4	16/1220	43[f]	58			
Environment Canada Buoy 44251 Nickerson Bank 46.44°N 53.39°W	16/1720	986.1	16/1820	37[f]	48			
Environment Canada Buoy 44255 NE Burgeo Bank 47.27°N 57.34°W	16/1720	995.0	16/2020	35[f]	45			
Environment Canada Buoy 44140 Tail of the Bank 47.87°N 51.47°W	16/1620	1010.8	16/1620	30[f]	37			
Environment Canada Buoy 44137 Scotian Slope 42.23°N 62.02°W	16/0820	999.7	16/1320	28[f]	35			
Environment Canada Buoy 44150 La Have Bank 42.50°N 64.02°W	16/0620	1003.9	16/1420	27[f]	34			
Environment Canada Buoy 44139 Banqureau Banks 44.24°N 57.10°W	16/1320	988.9	16/1820	26[f]	33			

[a] Date/time is for sustained wind when both sustained and gust are listed.

[b] Except as noted, sustained wind averaging periods for C-MAN and land-based ASOS reports are 2 min; buoy averaging periods are 8 min.

[c] Storm surge is water height above normal astronomical tide level.

[d] Storm tide is water height above Mean Lower Low Water.

[e] Sustained wind averaging period is 1 min.
[f] Sustained wind averaging period is 10 min.

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Maria, 6–16 September 2011. Mean errors for the 5-yr period 2006-10 are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Maria)	36.6	62.8	88.6	109.1	144.9	210.1	268.8
OCD5 (Maria)	52.1	124.7	207.9	277.8	355.0	397.1	442.1
Forecasts	35	33	31	29	25	21	17
OFCL (2006-10)	31.0	50.6	69.9	89.5	133.2	174.2	214.8
OCD5 (2006-10)	47.7	98.3	156.4	218.1	323.3	402.2	476.1

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Maria, 6–16 September 2011. 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	37.2	68.1	89.8	110.7	158.4	232.6	313.3
OCD5	50.5	103.3	184.2	273.6	313.3	411.8	459.1
GFSI	**35.1**	**61.4**	**80.1**	**99.2**	**134.8**	246.5	335.1
GHMI	37.9	71.2	102.0	134.4	207.2	295.4	406.3
HWFI	42.3	84.0	109.1	138.0	209.0	322.4	333.7
GFNI	**36.4**	73.3	103.2	127.2	**157.7**	**203.7**	**183.0**
NGPI	46.5	88.9	124.5	152.8	204.1	292.6	334.4
EGRI	41.4	**63.6**	**76.5**	**98.9**	162.5	275.0	358.5
FSSE	39.1	74.1	101.2	137.0	215.7	291.3	369.0
TCON	**36.0**	**65.6**	**83.8**	**104.4**	**150.6**	**230.3**	**302.1**
TVCA	**32.9**	**62.6**	**80.7**	**98.0**	**132.4**	**202.1**	**263.7**
TVCE	**34.2**	**66.0**	**85.9**	**105.3**	**141.5**	**214.0**	**273.3**
TVCC	**32.6**	**61.6**	**79.2**	**98.8**	**136.2**	**203.2**	**270.8**
GUNA	**37.0**	**66.7**	**87.1**	**107.6**	**155.2**	243.3	**306.8**
LBAR	45.5	80.9	129.5	180.1	248.0	327.9	387.6
BAMD	47.3	75.8	101.6	124.8	200.2	276.0	**303.7**
BAMM	48.4	71.6	107.8	142.4	181.9	296.6	**269.0**
BAMS	63.5	103.6	162.5	224.8	264.3	347.9	**270.6**
Forecasts	30	27	27	26	21	18	11

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Maria, 6–16 September 2011. Mean errors for the 5-yr period 2006-10 are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL (Maria)	**3.9**	**5.0**	**5.6**	**7.6**	**8.8**	**6.9**	**10.9**
OCD5 (Maria)	5.3	7.4	8.2	10.0	14.2	15.7	21.2
Forecasts	35	33	31	29	25	21	17
OFCL (2006-10)	7.2	11.0	13.2	15.1	17.2	17.9	18.7
OCD5 (2006-10)	8.5	12.3	15.4	17.8	20.2	21.9	21.7

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Maria, 6–16 September 2011. 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 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	3.4	5.0	5.9	7.3	8.6	5.8	10.0
OCD5	4.9	7.5	8.7	10.1	15.0	15.6	21.4
GHMI	4.1	7.9	13.4	19.5	31.0	35.7	44.3
HWFI	5.6	8.9	11.3	14.4	18.1	17.1	20.6
GFNI	5.2	6.7	10.5	14.9	26.4	28.7	36.6
FSSE	4.0	6.3	7.1	9.2	11.1	10.5	14.6
DSHP	4.1	5.1	6.7	7.8	11.8	12.8	14.6
LGEM	4.7	6.2	7.0	**7.1**	**8.0**	7.9	10.0
ICON	3.8	5.3	6.6	8.5	13.9	15.2	17.9
IVCN	3.7	5.3	6.7	9.2	16.2	17.7	20.8
Forecasts	32	30	28	26	21	18	14

Table 6. Watch and warning summary for Hurricane Maria, 6–16 September 2011.

Date/Time (UTC)	Action	Location
08/0300	Tropical Storm Watch issued	Antigua, Anguilla, Barbuda, Montserrat, Nevis, St. Kitts
08/1200	Tropical Storm Watch issued	Martinique, Guadeloupe, St. Barthelemy, St. Martin
08/1500	Tropical Storm Watch issued	Dominica, St. Maarten, Saba, St. Eustatius
08/2230	Tropical Storm Watch changed to Tropical Storm Warning	Guadeloupe
09/0300	Tropical Storm Watch changed to Tropical Storm Warning	St. Maarten, Saba, St. Eustatius
09/0300	Tropical Storm Watch issued	British Virgin Islands, Puerto Rico, U.S. Virgin Islands
09/0900	Tropical Storm Watch changed to Tropical Storm Warning	Antigua, Anguilla, Barbuda, Montserrat, Nevis, St. Kitts, British Virgin Islands, U.S. Virgin Islands
09/1500	Tropical Storm Watch changed to Tropical Storm Warning	Puerto Rico, Dominica
09/1615	Tropical Storm Watch changed to Tropical Storm Warning	Martinique, St. Barthelemy, St. Martin
10/1200	Tropical Storm Warning discontinued	Dominica, Guadeloupe, Martinique
10/1500	Tropical Storm Warning discontinued	All
13/0900	Tropical Storm Watch issued	Bermuda
13/2100	Tropical Storm Watch changed to Tropical Storm Warning	Bermuda
14/1200	Hurricane Watch issued	Bermuda
15/1800	Tropical Storm Watch issued	Arnolds Cove to Brigus South, Newfoundland, Canada
15/1800	Hurricane Watch discontinued	Bermuda

15/2100	Hurricane Watch issued	Arnolds Cove to Brigus South, Newfoundland, Canada
15/2100	Tropical Storm Warning issued	Arnolds Cove to Jones Harbor, Newfoundland, Canada
15/2100	Tropical Storm Warning discontinued	Bermuda
16/0600	Hurricane Watch and Tropical Storm Warning changed to Hurricane Warning	Arnolds Cove to Brigus South, Newfoundland, Canada
16/0600	Tropical Storm Warning modified to	Arnolds Cove to Stones Cove, Newfoundland, Canada
16/0600	Tropical Storm Warning issued	Brigus South to Charlottestown, Newfoundland, Canada
16/2100	All Warnings discontinued	

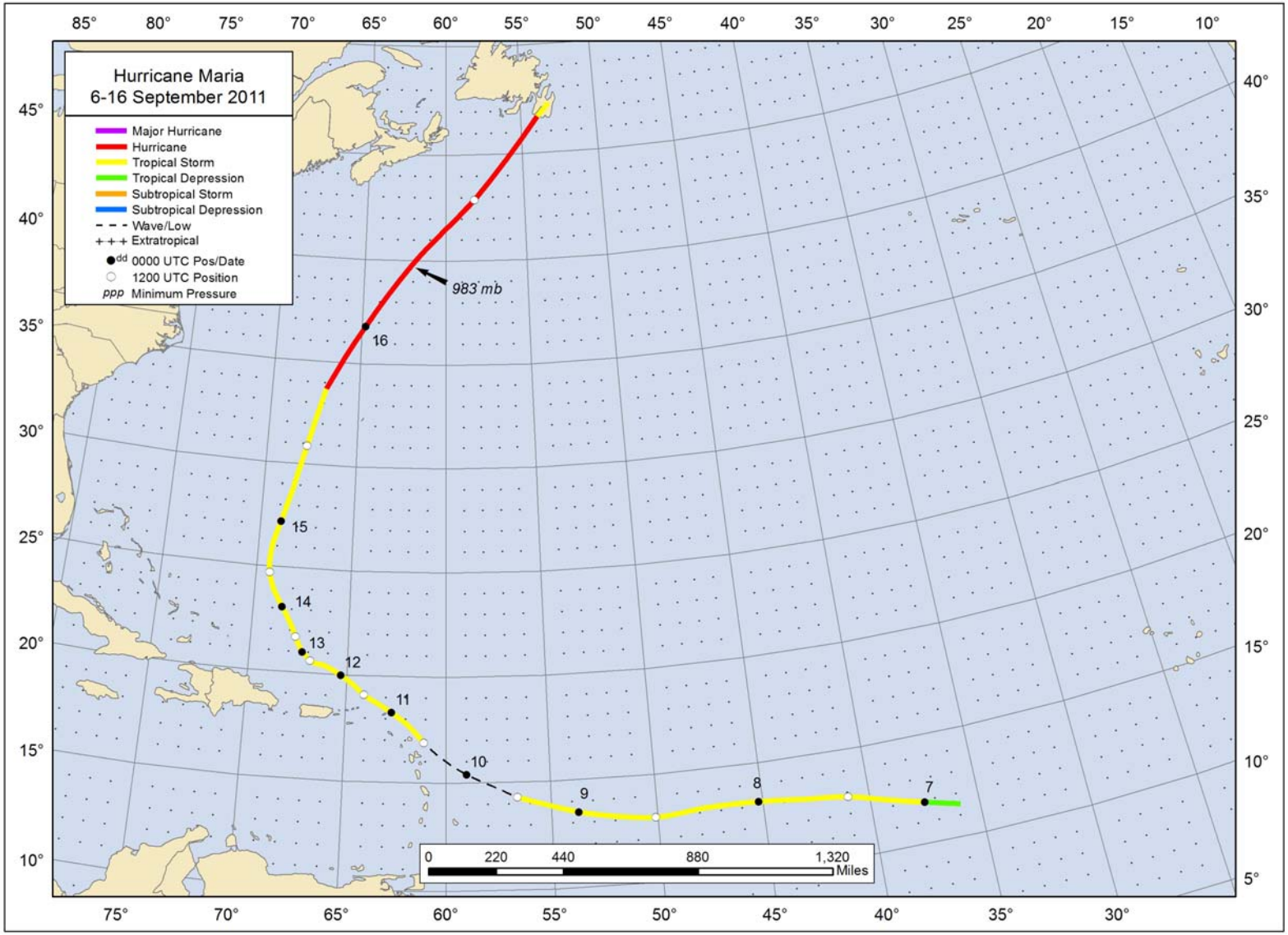

Figure 1. Best track positions for Hurricane Maria, 6–16 September 2011.

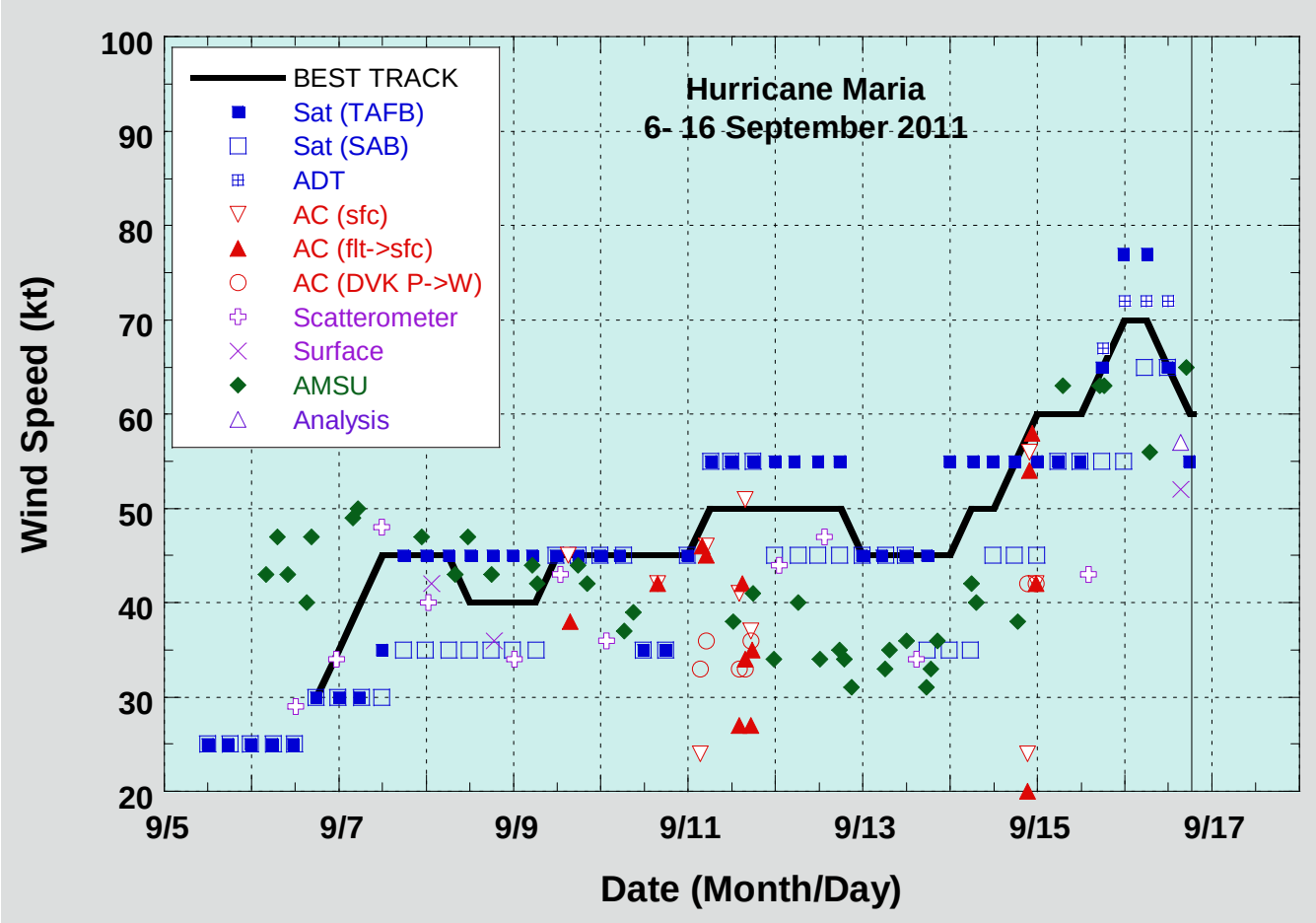

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Maria, 6–16 September 2011. Aircraft observations have been adjusted for elevation using an 80% adjustment factor for observations from 850 mb. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC and solid vertical line corresponds to landfall.

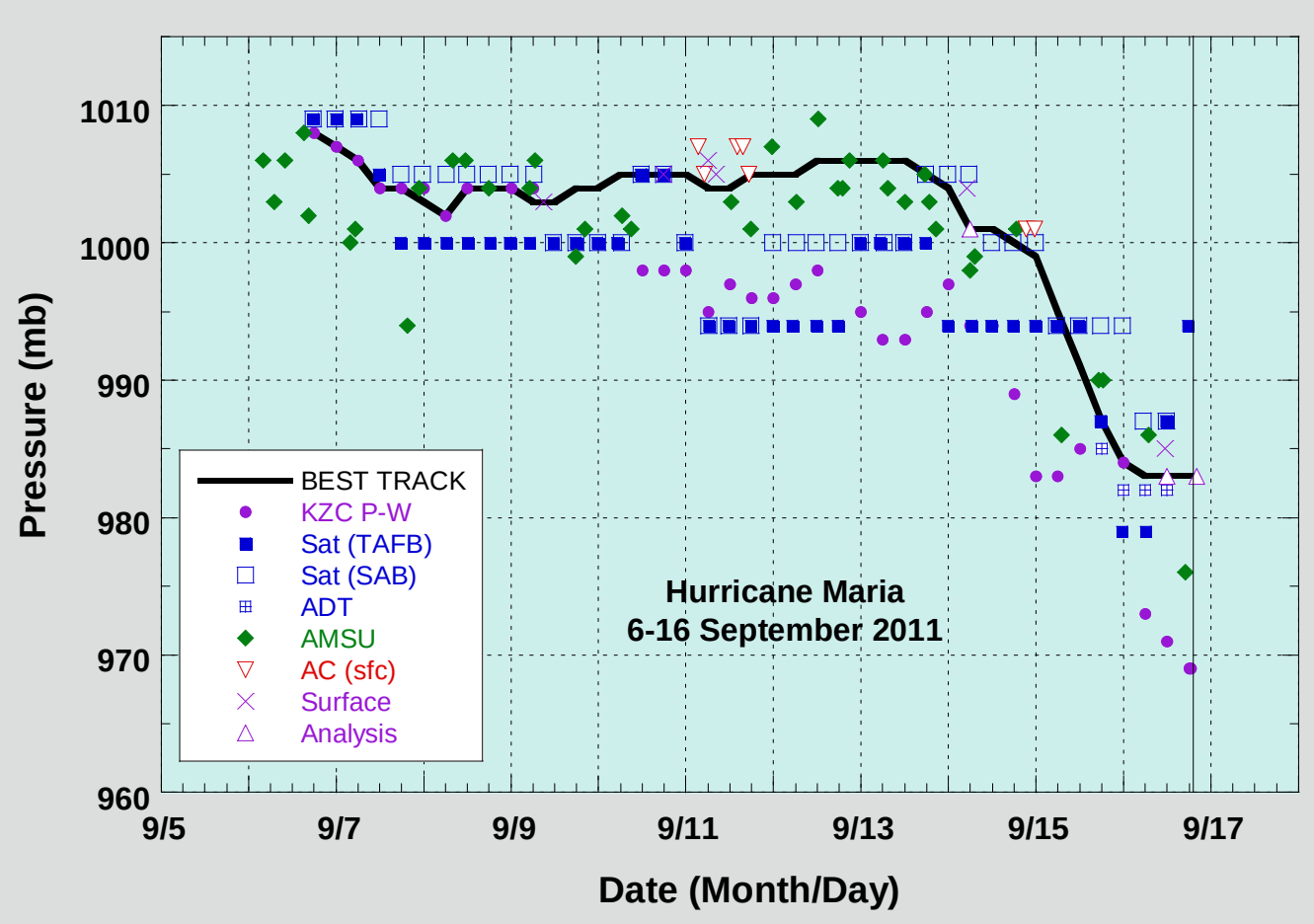

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Maria, 6–16 September 2011. Advanced Dvorak Technique estimates represent linear averages over a three-hour period centered on the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. The KZC P-W values are obtained by applying the Knaff-Zehr-Courtney pressure-wind relationship to the best track wind data. Dashed vertical lines correspond to 0000 UTC and solid vertical line corresponds to landfall.

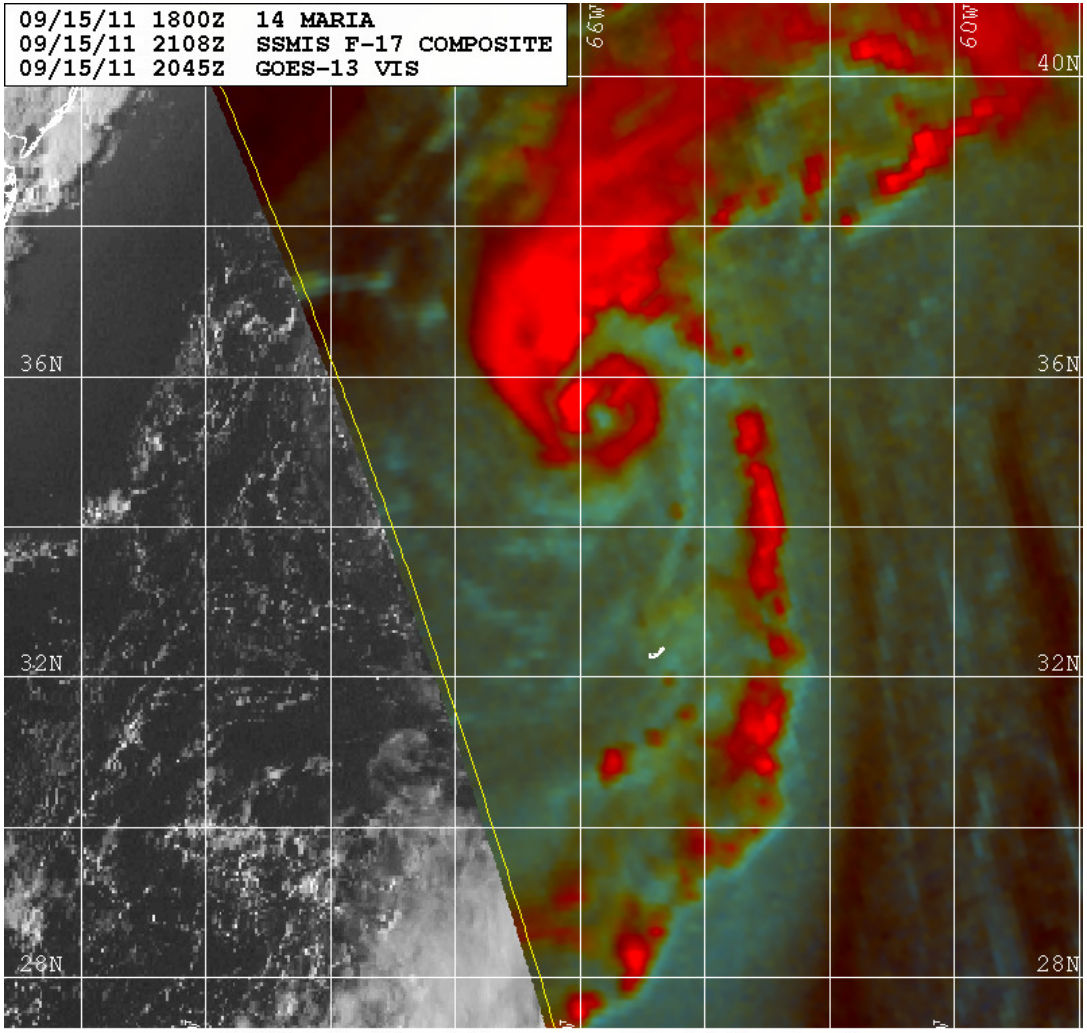

Figure 4. SSMIS 91-GHz color composite satellite image of Hurricane Maria at 2108 UTC 15 September 2011 at the time of peak intensity. Image courtesy U.S. Navy Fleet Numerical Meteorology and Oceanography Center, Monterey, California.

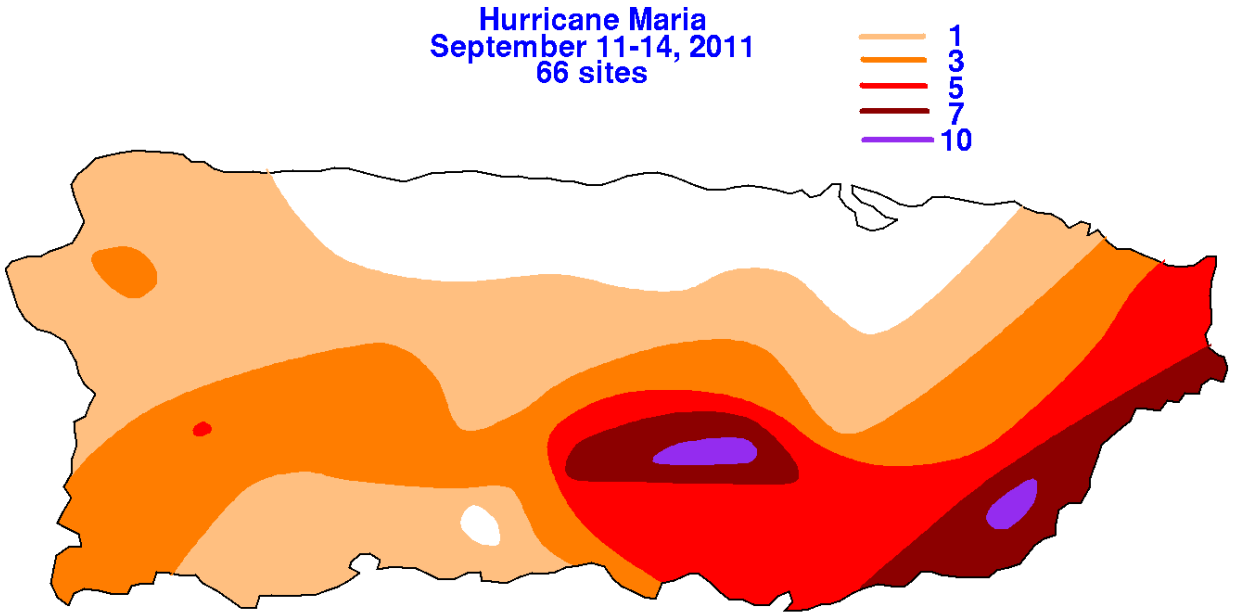

Figure 5. Analyzed rainfall totals (inches) in Puerto Rico from Maria. Analysis and image courtesy of David Roth of the NOAA Hydrometeorological Prediction Center.

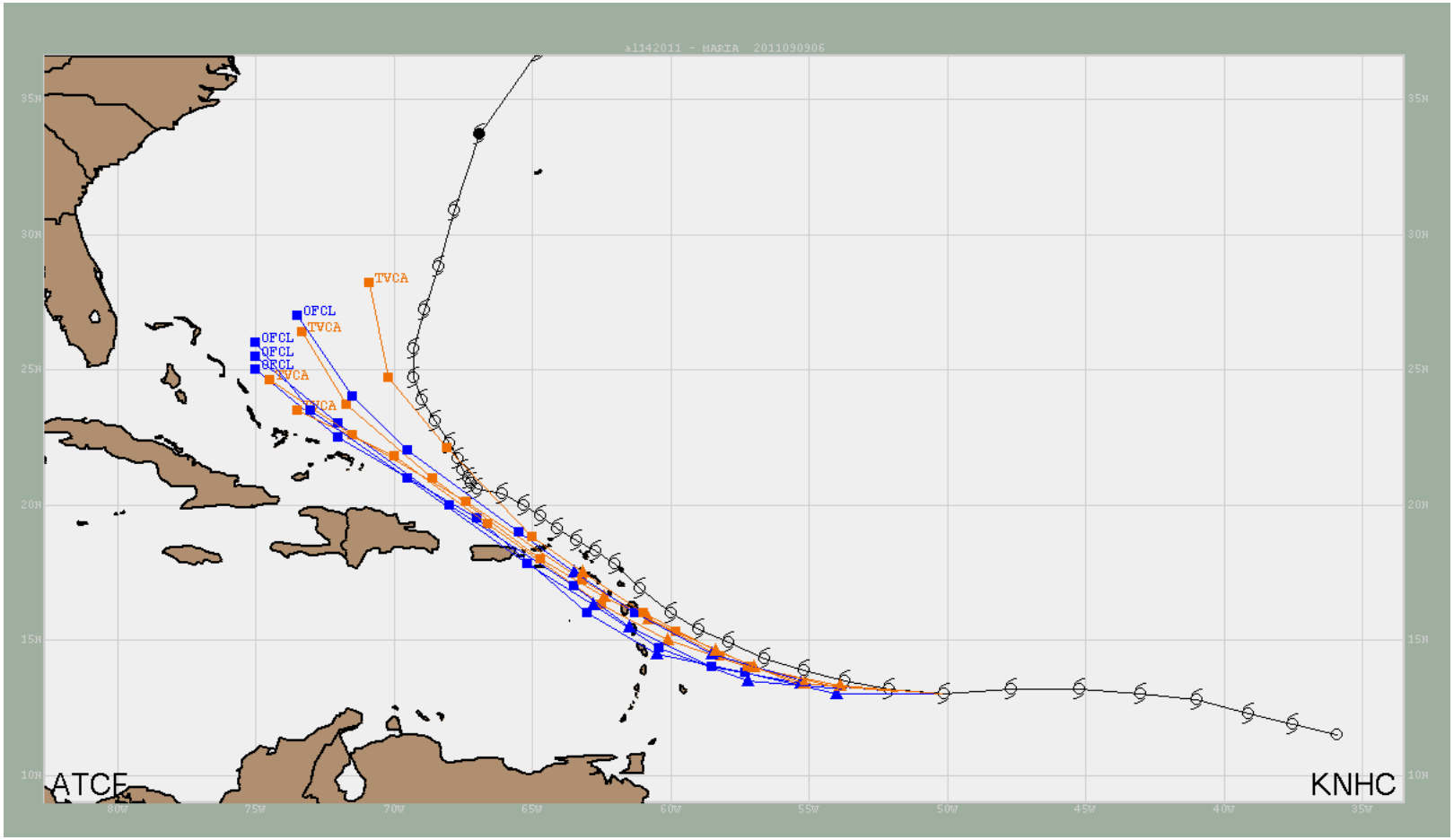

Figure 6. Official (blue) and TVCA consensus model (orange) 5-day track forecasts for Maria issued from 1200 UTC 8 September through 0600 UTC 9 September 2011. The black line shows the best track of Maria.

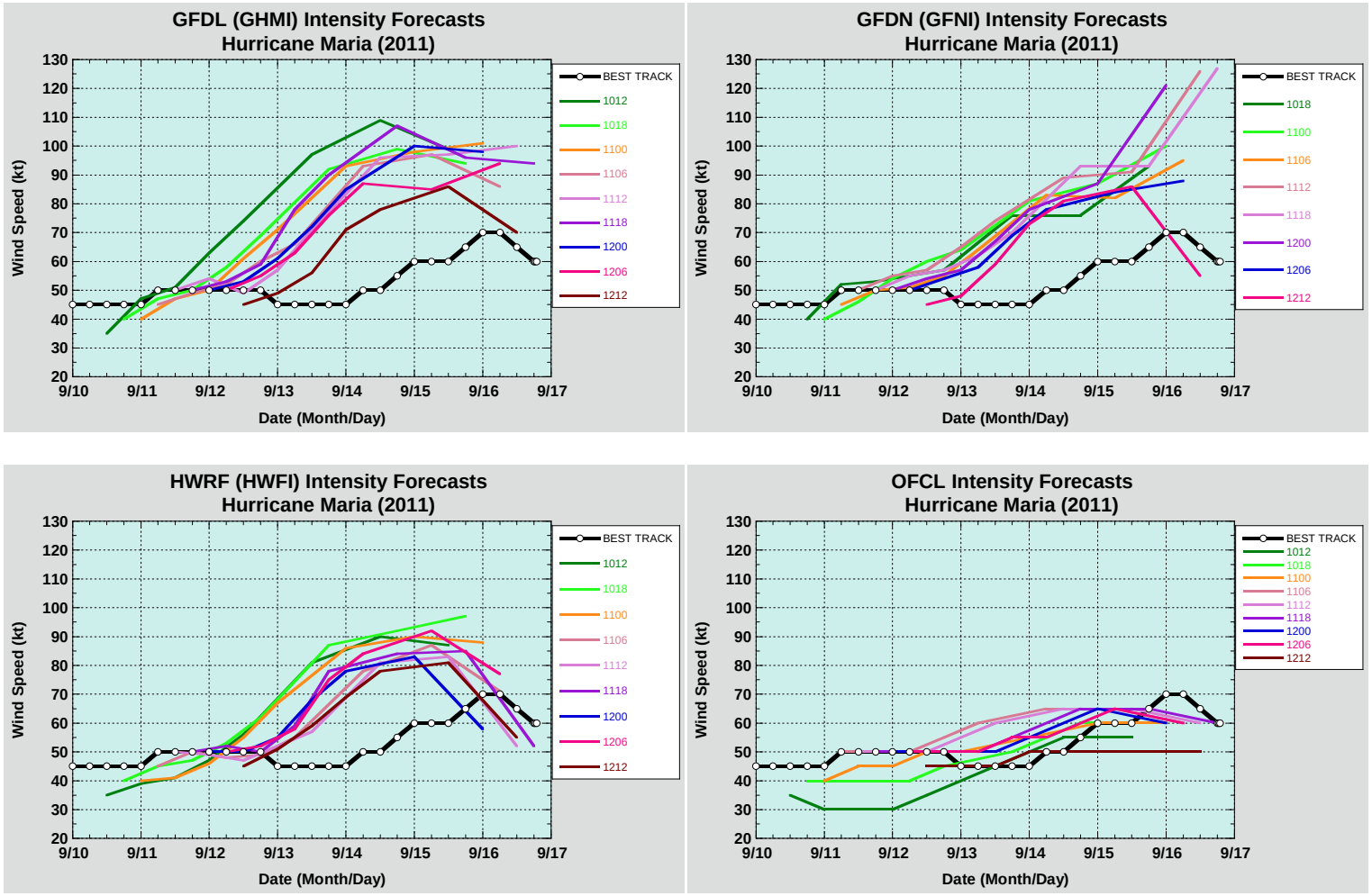

Figure 7. Intensity forecasts (colored lines, kt) for Hurricane Maria from 1200 UTC 10 September through 1200 UTC 12 September 2011 from the GFDL model (GHMI, upper left), the U.S. Navy version of the GFDL model (GFNI, upper right), the HWRF model (HWFI, lower left), and the official forecast (OFCL, lower right). The solid black line represents the best track intensity of Maria.