NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE MARIA

(AL152017)

16–30 September 2017

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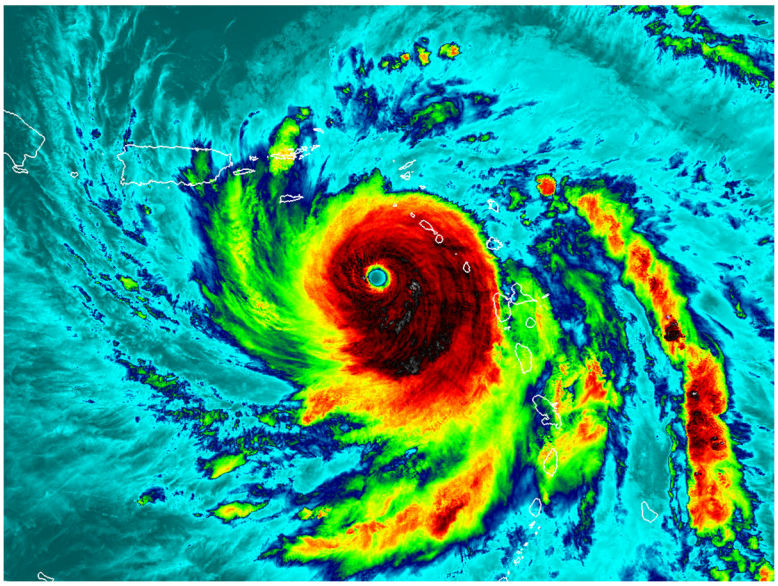

VIIRS SATELLITE IMAGE OF HURRICANE MARIA NEARING PEAK INTENSITY AT 1942 UTC 19 SEPTEMBER 2017. IMAGE COURTESY OF UW-CIMSS.

Maria was a very severe Cape Verde Hurricane that ravaged the island of Dominica at category 5 (on the Saffir-Simpson Hurricane Wind Scale) intensity, and later devastated Puerto Rico as a high-end category 4 hurricane. It also inflicted serious damage on some of the other islands of the northeastern Caribbean Sea. Maria is the third costliest hurricane in United States history.

[1] Original report date 5 April 2018. Second version on 10 April 2018 corrected damage photo of Dominica in Fig. 9. Third version on 14 February 2019 corrected best track latitude and longitude values in Table 1 at 0000 UTC 21 September 2017, 0600 UTC 29 September 2017, and 1200 UTC 29 September 2017. This version (4 January 2023) includes a revised death toll for Puerto Rico.

Hurricane Maria

16–30 SEPTEMBER 2017

SYNOPTIC HISTORY

Maria originated from a well-defined tropical wave that departed the west coast of Africa on 12 September. The system moved westward over the tropical Atlantic for the next few days while producing scattered and disorganized deep convection. By 15 September, showers and thunderstorms increased and began to show signs of organization, with some curved cloud bands developing. Deep convection then quickly became more consolidated and better organized, and it is estimated that a tropical depression formed about 580 n mi east of Barbados by 1200 UTC 16 September. 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[2].

Moving westward to the south of a mid-level high pressure area, the cyclone strengthened into a tropical storm around 1800 UTC on 16 September. Maria turned toward the west-northwest shortly thereafter, and quickly intensified into a hurricane by 1800 UTC on 17 September. While situated in an environment of warm sea surface temperatures and light vertical shear, the hurricane strengthened extremely rapidly. Maria became a 100-kt major hurricane by 1200 UTC 18 September, and just 12 h later, as it neared Dominica, it became a category 5 hurricane with maximum winds of 145 kt. The hurricane made landfall on the island with that intensity and an estimated minimum central pressure of 922 mb around 0115 UTC 19 September.

After striking Dominica, Maria continued moving west-northwestward and entered the northeastern Caribbean Sea. Slight weakening had occurred due to the system's interaction with the mountainous island of Dominica, but the hurricane soon regained intensity and strengthened to its peak intensity of 150 kt with a minimum pressure of 908 mb around 0300 UTC 20 September while centered about 25 n mi south of St. Croix. Maria moved west-northwestward to northwestward toward Puerto Rico and, after reaching maximum intensity, underwent an eyewall replacement with an outer eyewall becoming more dominant by the time the center of the system reached Puerto Rico (Figures 4a and 4b). The hurricane weakened somewhat before its landfall on that island due to the eyewall replacement, but also grew in size. Maria's center crossed the southeast coast of Puerto Rico near Yabucoa around 1015 UTC 20 September, and the hurricane's maximum winds at that time were near 135 kt, i.e., just below the threshold of category 5 intensity. The hurricane's center crossed the island, roughly diagonally from southeast to northwest, for several hours and emerged into the Atlantic around 1800 UTC 20 September. By that time, Maria had weakened after interacting with the land mass of Puerto Rico and its maximum winds were estimated to be 95 kt.

[2] 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.

Over the next couple of days, the hurricane moved northwestward along the southwestern periphery of a mid-level high over the western Atlantic while gradually restrengthening. Although Maria never regained all of its former intensity, its maximum winds increased to near 110 kt by 0000 UTC 22 September while the hurricane was centered about 60 n mi southeast of Grand Turk Island. Maria turned toward the north-northwest, and its center passed 30 to 40 n mi east and northeast of the Turks and Caicos Islands on 22 September. Moderate southwesterly vertical shear prevented any additional strengthening during that period. The system maintained major hurricane status until 0600 UTC 24 September, while turning toward the north. Maria continued to gradually weaken, and it lost its eyewall structure by 25 September while continuing northward at a slow forward speed well offshore of the southeastern U.S. coast. The cyclone then weakened to category 1 status, and by 0600 UTC 27 September the center of the 65-kt hurricane passed about 130 n mi east of Cape Hatteras, North Carolina. On 28 September, Maria turned sharply toward the east and began to accelerate as it weakened to a tropical storm. Moving rapidly eastward to east-northeastward, the system became an extratropical cyclone by 1800 UTC 30 September while centered about 465 n mi southeast of Cape Race, Newfoundland. The cyclone moved east-northeastward until dissipation over the north Atlantic about 400 n mi southwest of Ireland by 1800 UTC 2 October.

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 22 flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command, and 8 flights of the NOAA Hurricane Hunter P-3 aircraft. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Global Precipitation Mission (GPM), 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 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.

Winds and Pressure

Maria's peak intensity of 150 kt is based on a blend of SFMR-observed surface winds of 152 kt and 700-mb flight-level winds of 157 kt. Maria's 65-kt intensity increase over 24 h on 18 September makes it tied for the sixth-fastest intensifying hurricane in the Atlantic basin record.

The intensity of the hurricane when it struck Dominica, 145 kt, is based on an SFMR-observed surface wind of 152 kt which, based on quality control by data processing software, is believed to be somewhat inflated, and a maximum 10-min wind of 130 kt measured at Douglas-

Charles Airport on the island, which conservatively corresponds to a 1-min wind of 143 kt. Maria is the strongest hurricane on record to make landfall on Dominica (or strike within 60 n mi of that island).

Maria's minimum central pressure of 908 mb is based on an eye dropsonde measurement by the Air Force Hurricane Hunters of 910 mb with 23-kt winds at the surface at 0313 UTC 20 September. This is the lowest pressure on record of any hurricane in the Atlantic basin east of 70°W, and breaks the record that had been set just a couple of weeks earlier by Irma of 914 mb.

The landfall intensity of the cyclone in Puerto Rico, 135 kt, is based on an extrapolation of the weakening trend noted in the aircraft data after the eyewall replacement began several hours earlier. There were no believable Doppler-derived winds from the San Juan WSR-88D radar that supported a higher intensity. It should be noted, however, that in Puerto Rico, winds of category 5 intensity were almost certainly felt at some elevated locations on the island.

The landfall pressures of the hurricane in Dominica and Puerto Rico of 922 and 920 mb, respectively, are based on an extrapolation of the system's deepening and filling trends before making landfall in those islands. Several storm chasers observed pressures higher than the estimated minimum value in Puerto Rico, but these observers were not thought to be in the exact center of the hurricane. Maria is the strongest hurricane to make landfall in Puerto Rico since a category 5 hurricane in 1928 (known as Segundo San Felipe).

Maria's eyewall replacement early on 20 September resulted in roughly a tripling of its eye diameter, from 9 n mi to about 28 n mi, prior to landfall in Puerto Rico. This event was likely a major contributor to weakening, but also increased the areal exposure of the island to the hurricane's highest winds.

A peak sustained wind of 93 kt with a gust to 119 kt was reported at St. Croix near the northeast edge of Maria's eyewall. Las Mareas, on the south coast of Puerto Rico, recorded a 1-min sustained wind of 94 kt with a gust to 109 kt in the western eyewall of Maria. Wind gusts to hurricane force were recorded in Guadeloupe and on the northeast coast of the Dominican Republic.

Sustained winds at the low end of tropical storm force occurred over the North Carolina Outer Banks due to Maria.

It should be noted that in Figure 2, beginning around 24 September, Maria's actual maximum winds were as much as 20-30 kt lower than what would be derived from a standard pressure-wind relationship [AC(DVK->W)]. This is mainly due to the expansion of the cyclone's circulation while it moved into higher latitudes.

Storm Surge[3]

The combined effect of the surge and tide produced maximum inundation levels of 6 to 9 ft above ground level to the north of Maria's landfall along the coasts of Humacao, Naguabo, and Ceiba municipalities in Puerto Rico. Figure 5 provides an analysis of maximum inundation heights along the coasts of Puerto Rico and the U.S. Virgin Islands, and Figure 6 provides peak water levels recorded by tide gauges, relative to Mean Higher High Water (MHHW). The United States Geological Survey (USGS) measured high water marks of 5.1 ft and 4.9 ft above ground level inside structures at Punta Santiago in Humacao. Another high water mark was surveyed at 9.5 ft above the Puerto Rico Vertical Datum of 2002 (PRVD), which converts to about 9 ft MHHW. These data suggest that maximum inundation levels along the immediate shoreline were as high as 9 ft above ground level in these municipalities. Elsewhere along the southeastern coast of Puerto Rico, maximum inundation levels are estimated at 4 to 7 ft above ground level, primarily in the municipalities of Yabucoa, Maunabo, Patillas, and Arroyo. A Puerto Rico Seismic Network tide gauge at Yabucoa Harbor measured a water level of 5.3 ft MHHW, but the sensor went offline for a period and may not have recorded the peak water level.

Maximum inundation levels of 3 to 5 ft above ground level occurred along the coast of northeastern Puerto Rico, especially in the municipalities of Ceiba and Fajardo, and along much of the southern coast from Ponce eastward. A tide gauge in Fajardo measured a water level of 2.2 ft MHHW before it went offline. A USGS storm tide sensor installed on a public dock at Puerto Chico in Fajardo measured a wave-filtered water level of 2.8 ft above the sensor (also about 2.8 ft MHHW), and the waves themselves contributed another 2 ft or so to the total water level, yielding almost 5 ft of inundation in that area. On the southern coast, a high water mark of 5.2 ft PRVD was surveyed at Playa de Salinas, which converts to about 4.8 ft MHHW and supports an estimated maximum inundation of 5 ft above ground level.

Maximum inundation levels of 2 to 4 ft above ground level occurred along much of the northern coast of Puerto Rico. A National Ocean Service (NOS) tide gauge in San Juan Bay measured a peak water level of 2.4 ft MHHW, but the sensor went offline for a period and may not have recorded the highest water level. Farther west, a tide gauge at Arecibo measured a peak water level of 1.9 ft MHHW. Elsewhere, peak water levels along the northwestern, western, and southwestern coasts of Puerto Rico are estimated to have been 1 to 3 ft above ground level.

Post-storm surge simulations suggest that maximum inundation levels of 3 to 5 ft above ground level occurred on Vieques and St. Croix. Tide gauges at Isabel Segunda, Vieques, and Lime Tree Bay, St. Croix, measured peak water levels of 2.0 ft MHHW and 2.8 ft MHHW, respectively, but both of these sensors went offline and may not have recorded the highest water levels. Surge simulations and available tide gauge observations also suggest that maximum inundation levels of 1 to 3 ft above ground level occurred on Culebra, St. Thomas, and St. John.

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[3] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

Maximum inundation levels of 1 to 3 ft above ground level occurred along the coast of North Carolina as Maria moved by offshore. Figure 7 provides maximum water levels from tide gauges along the coast of North Carolina. The NOS tide gauge at the U.S. Coast Guard station at Hatteras, North Carolina, measured a peak water level of 2.7 ft MHHW on the back side of the Outer Banks in Pamlico Sound. Water levels measured by other tide stations in North Carolina and southeastern Virginia were less than 2 ft MHHW.

Although there appears to have been considerable damage due to storm surge and/or wave action in Dominica, no water level measurements are available from that island.

Rainfall and Flooding

In addition to its furious winds, the hurricane produced enormous amounts of rain on the islands over which it swept. Dominica experienced torrential rains from Maria, with a maximum observed total of 22.8 inches. The rains caused serious flooding and mud slides across that island. Even heavier rainfall occurred in Puerto Rico, where one location had a storm total of nearly 38 inches (Fig. 8). River discharges at many locations in the island were at record or near-record levels. Severe flooding and mud slides affected most of the island, with the most significant flooding associated with the La Plata River. Heavy rains, with totals of at least 10 to 13 inches, also occurred in Guadeloupe and portions of the Dominican Republic, and these rains also likely led to significant flooding and mud slides.

Tornadoes

Three small tornadoes were observed by a storm chaser near Yabucoa, Puerto Rico, but these have not been confirmed by the National Weather Service.

CASUALTY AND DAMAGE STATISTICS

In Puerto Rico, the death toll from Maria was staggering. Based on a study from George Washington University's Milken Institute School of Public Health (2018), the government of Puerto Rico has estimated there were 2975 fatalities on that island due to Maria. This total includes both direct and indirect deaths[4] since it was nearly impossible to differentiate between the two types of fatalities for this event.

Maria caused 31 direct deaths in Dominica with 34 missing. In Guadeloupe, two direct fatalities are attributed to Maria: one person died from a falling tree, and another was swept out

[4] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as “direct” deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect” deaths.

to sea. In St. Thomas, one person died from drowning, and another was killed by a mud slide. Four persons were swept away by floodwaters, and another individual perished in a mud slide in the Dominican Republic. Three persons died due to floodwaters in Haiti. In the mainland United States, three persons drowned due to rip currents at the Jersey Shore, and there was a fourth drowning death at Fernandina Beach, Florida.

Maria caused catastrophic damage in Dominica, with the majority of structures seriously damaged or destroyed, and most trees and vegetation were downed and/or defoliated. According to media reports, the estimated damage total in Dominica is at least $1.31 billion. The agricultural sector was essentially eliminated. The once-lush tropical island was effectively reduced to an immense field of debris. In a Facebook post just after the hurricane hit, Dominica's Prime Minister, Roosevelt Skerrit, described the damage as "mind-boggling". The roofs of the majority of buildings and homes were either damaged or blown off. There was extensive damage to roads. Power, phone, and internet service was cut off, leaving the country almost incommunicado with the outside world. Figure 9 shows some examples of the damage in Dominica.

In Guadeloupe, to the north of Dominica, hurricane-force wind gusts and heavy rain caused a great deal of damage, especially along the southern portions of Basse-Terre Island. An estimated 80,000 homes were without electricity, and almost the entire banana crop was destroyed. An estimated $120 million in damage was reported for Guadeloupe.

To the south of Dominica, the island of Martinique had mostly minor damage.

Among all the U.S. Virgin Islands, St. Croix was the most severely affected by Maria, having experienced the northern portion of the outer eyewall. Wind damage was evident across the entire island with many fallen trees, downed signs, roof damage and complete destruction of many wooden houses. Excessive rainfall generated significant flooding and mud slides across the island. In St. Thomas and St. John, most of the roofs, signs and trees had already been destroyed or damaged earlier by Hurricane Irma, but large rainfall accumulations generated flooding and mud slides across all these islands.

Puerto Rico was devastated by winds and floods. The NOAA estimate of damage in Puerto Rico and the U.S. Virgin Islands due to Maria is 90 billion dollars, with a 90% confidence range of +/-$25.0 billion, or $65.0-$115.0 billion, which makes Maria the third costliest hurricane in U.S. history, behind Katrina (2005) and Harvey (2017). Maria is by far the most destructive hurricane to hit Puerto Rico in modern times, as the previous costliest hurricane on record for the island was Georges in 1998, which in 2017 dollars "only" caused about 5 billion dollars of damage. The combined destructive power of storm surge and wave action from Maria produced extensive damage to buildings, homes and roads along the east and southeast coast of Puerto Rico as well as the south coasts of Vieques and St. Croix. Along these areas, marinas and harbors were severely damaged due to the combination of the waves and currents associated with the surge. A storm surge also caused significant damage over the northwestern coastal area of Puerto Rico. Across the island, many buildings suffered significant damage or were destroyed. Numerous trees were downed, splintered and/or defoliated. River flooding was unprecedented in some areas, especially in the northern portion of the island. The La Plata River flooded the entire alluvial valley including the municipality of Toa Baja, where hundreds of families needed to be rescued from their roof tops. Maria knocked down 80 percent of Puerto Rico's utility poles and all transmission lines, resulting in the loss of power to essentially all of the island's 3.4 million

residents. Practically all cell phone service was lost and municipal water supplies were knocked out. At of the end of 2017, nearly half of Puerto Rico's residents were still without power, and by the end of January 2018, electricity had been restored to about 65% of the island. Just before Maria's center made landfall, extreme winds destroyed the WSR-88D radar in Puerto Rico (Figure 10). Other examples of damage in Puerto Rico and St. Croix are shown in Figure 11.

On the island of Vieques, all wooden structures were either damaged or destroyed. The island of Culebra had recently experienced major damage due to Hurricane Irma, rendering the remaining structures on the island extremely vulnerable to Maria's winds. There was total destruction of many wooden houses, along with blown off roofs and sunken boats.

Hundreds of homes were either damaged or destroyed in the northern part of the Dominican Republic, and about 60,000 people lost power in that country. Many communities were cut off as a result of flooding and/or mud slides.

There was no significant damage in North Carolina.

FORECAST AND WARNING CRITIQUE

The wave from which Maria developed was first mentioned in both the 48- and 120-h Tropical Weather Outlooks with a "low" (<40%) chance of development 60 h prior to Maria's formation. The genesis probabilities within 48 h and 120 h were raised to "medium" (40–60%) 30 h and 54 h prior to formation, respectively, and to "high" (>60%) only 18 h and 42 h before formation, respectively (Table 5). Clearly, the genesis of Maria was not well forecast, and one reason for the poor genesis forecasts was a failure of the global models to definitively predict tropical cyclone formation until very soon before it actually occurred. Figure 12 shows 96- and 120-h GFS and ECMWF forecasts verifying at the time of Maria's genesis; it can be seen that neither global model predicted the development of a closed surface circulation.

A verification of NHC official track forecasts for Maria is given in Table 6a. The mean official track forecast errors increased about 20 n mi per day, ranging from around 20 n mi at 24 h to around 120 n mi at 120 h. These errors were about 50% smaller than the mean official errors for the previous 5-yr period at all forecast intervals (Figure 13). Figure 14 shows that all of the official forecasts issued from the time of Maria's formation up to the night before its second landfall correctly showed that the hurricane would strike Puerto Rico. A homogeneous comparison of the official track errors with selected guidance models is given in Table 6b. Most of the models performed quite well for Maria, including the simple and corrected consensus forecasts. It should be noted that the GFS, which has typically been bested by the ECMWF for track prediction in the Atlantic basin, was superior to the ECMWF at 48 through 120 h.

A verification of NHC official intensity forecasts for Maria is given in Table 7a. The mean official forecast intensity errors were 10 to 15 kt from 24 through 72 h, but were less than 10 kt at days 4 and 5. These errors were 15% to 25% higher than the mean official errors for the previous 5-yr period through 48 h, but 10% lower than the long-term mean at 72 h and 35% to 45% lower at 96 and 120 h. A homogeneous comparison of the official intensity errors with selected guidance

models is given in Table 7b. The Florida State University Superensemble (FSSE) had lower mean errors than the official forecasts at all forecast intervals. One issue of note regarding intensity forecasts for Maria was how poorly the rapid intensification episode of 18 September was anticipated. Figure 15 shows the various intensity guidance models for the forecast beginning at the onset of the episode, and it can be seen the guidance substantially underpredicted Maria's strengthening. It should be noted that the SHIPS model Rapid Intensification Index showed a significant probability, i.e. about a 50% chance, of rapid intensification at this time and the official forecast showed considerable strengthening, but still not nearly enough strengthening. Notwithstanding, beginning with the second official forecast, every NHC forecast indicated that Maria would become a major hurricane by the time it reached Puerto Rico, which was a remarkable 84 h of lead time. In addition, NHC began to forecast Maria making landfall on that island as a category 4 hurricane about 54 h in advance.

NHC's forecast for maximum storm surge inundation heights in Puerto Rico and the U.S. Virgin Islands (first issued at 1500 UTC 18 September) was 6 to 9 ft above ground level. Storm tide sensor data and high water mark observations indicate that maximum inundation of 6 to 9 ft above ground level occurred north of Maria's landfall location on the eastern side of Puerto Rico. The initial forecast for maximum storm surge heights in North Carolina (issued at 2100 UTC 24 September) was 2 to 4 ft above ground level. Water level observations indicate that peak water levels were on the lower end of that forecast range.

The NWS issued storm surge watches and warnings for portions of the North Carolina coast due to the potential for coastal inundation from Maria[5]. NWS first issued a Storm Surge Watch from Cape Lookout to Duck, North Carolina, including some portions of southern Pamlico and southern Albemarle Sounds, at 2100 UTC 24 September. The portion of that area from Ocracoke Inlet to Cape Hatteras was upgraded to a Storm Surge Warning at 1500 UTC 26 September. The water level observation from the U.S. Coast Guard station at Hatteras suggests that up to 3 ft of inundation (which NHC uses as a first-cut threshold for the storm surge watch/warning) may have occurred within the Storm Surge Warning area (Fig. 7).

Watches and warnings associated with Maria are given in Table 8. A Hurricane Warning was issued a little over 34 h before Maria made landfall in Dominica, and a little over 37 h before landfall in Puerto Rico.

In addition to its partners within the NWS, the NHC coordinated watches and warnings with a number of countries for areas around the Caribbean Sea, including Barbados (which has responsibility for Dominica), St. Lucia, France (for Martinique, Guadeloupe, and St. Martin), Antigua (which also has responsibility for Montserrat, St. Kitts, Nevis, Barbuda, Anguilla and the British Virgin Islands), the Netherlands (which has responsibility for Saba and St. Eustatius), St. Maarten, the Dominican Republic, and the Bahamas.

The NHC began providing Impact-Based Decision Support Services (IDSS) to emergency managers on 14 September, when Maria was a tropical wave in the central Atlantic and this IDSS continued through 27 September, when Maria moved away from the North Carolina coast. The IDSS included calls and briefings coordinated through the FEMA Hurricane Liaison Team, which

[5] Currently, storm surge watches and warnings are only issued for the Gulf and Atlantic coasts of the continental United States.

is embedded at the NHC. The briefings included the Territories of Puerto Rico and the U.S. Virgin Islands, FEMA Regions 2 and 3, as well as Federal and state video-teleconferences.

The NHC also collaborated with affected NWS offices (primarily San Juan) to ensure a consistent message, and NWS meteorologists provided IDSS for local and state emergency management offices during Maria.

ACKNOWLEDGMENTS

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Table 1. Best track for Hurricane Maria, 16–30 September 2017.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
16 / 1200	12.2	49.7	1006	30	tropical depression
16 / 1800	12.2	51.7	1004	40	tropical storm
17 / 0000	12.4	53.1	1002	45	"
17 / 0600	12.8	54.4	994	55	"
17 / 1200	13.3	55.7	990	60	"
17 / 1800	13.6	57.0	986	65	hurricane
18 / 0000	14.0	58.0	979	75	"
18 / 0600	14.3	59.0	977	80	"
18 / 1200	14.5	59.7	967	100	"
18 / 1800	14.9	60.4	956	110	"
19 / 0000	15.3	61.1	924	145	"
19 / 0115	15.4	61.3	922	145	"
19 / 0600	15.7	61.9	940	135	"
19 / 1200	16.1	62.7	931	140	"
19 / 1800	16.6	63.5	920	145	"
20 / 0000	17.0	64.3	909	150	"
20 / 0300	17.3	64.7	908	150	"
20 / 0600	17.6	65.1	913	140	"
20 / 1015	18.0	65.9	920	135	"
20 / 1200	18.2	66.2	935	115	"
20 / 1800	18.6	67.0	959	95	"
21 / 0000	19.0	67.6	958	95	"
21 / 0600	19.4	68.2	959	100	"
21 / 1200	19.9	68.8	959	100	"
21 / 1800	20.5	69.5	960	105	"
22 / 0000	20.8	70.0	953	110	"
22 / 0600	21.2	70.5	959	110	"
22 / 1200	21.9	70.9	958	110	"
22 / 1800	22.8	71.2	959	110	"
23 / 0000	23.7	71.6	953	105	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
23 / 0600	24.4	71.9	952	100	"
23 / 1200	25.1	72.1	952	100	"
23 / 1800	25.9	72.3	952	100	"
24 / 0000	26.6	72.4	945	100	"
24 / 0600	27.5	72.6	942	95	"
24 / 1200	28.4	72.8	947	95	"
24 / 1800	29.1	72.9	943	90	"
25 / 0000	29.7	72.9	947	85	"
25 / 0600	30.3	72.9	954	75	"
25 / 1200	30.8	73.0	961	70	"
25 / 1800	31.4	73.1	966	70	"
26 / 0000	32.0	73.1	966	70	"
26 / 0600	32.6	73.1	970	65	"
26 / 1200	33.3	73.1	970	65	"
26 / 1800	33.9	73.1	975	65	"
27 / 0000	34.4	73.0	975	65	"
27 / 0600	34.9	72.9	976	65	"
27 / 1200	35.4	72.8	977	65	"
27 / 1800	36.0	72.6	979	65	"
28 / 0000	36.6	72.2	979	65	"
28 / 0600	36.7	71.3	982	60	tropical storm
28 / 1200	36.8	70.0	982	60	"
28 / 1800	36.8	68.6	985	55	"
29 / 0000	36.9	66.8	985	55	"
29 / 0600	37.0	64.6	987	50	"
29 / 1200	37.0	62.0	988	50	"
29 / 1800	37.4	59.0	988	50	"
30 / 0000	38.1	55.6	988	50	"
30 / 0600	39.1	52.2	988	50	"
30 / 1200	40.0	48.8	988	50	"
30 / 1800	41.2	45.6	991	45	extratropical

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
01 / 0000	42.2	42.6	994	45	"
01 / 0600	43.4	39.4	996	45	"
01 / 1200	44.9	35.5	999	45	"
01 / 1800	46.5	31.0	1003	45	"
02 / 0000	47.5	26.5	1005	40	"
02 / 0600	48.0	22.0	1012	40	"
02 / 1200	48.0	17.0	1016	30	"
02 / 1800					dissipated
20 / 0300	17.3	64.7	908	150	maximum wind and minimum pressure
19 / 0115	15.4	61.3	922	145	landfall in Dominica
20 / 1015	18.0	65.9	920	135	landfall near Yabucoa, Puerto Rico

Table 3. Selected ship reports with winds of at least 34 kt for Hurricane Maria, 16–30 September 2017.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
19 / 0600	C6FM9	12.5	62.6	290 / 36	1015.3
23 / 1900	C6VV8	23.1	74.6	270 / 35	1007.6
23 / 2100	C6VV8	23.6	74.5	270 / 40	1007.6
25 / 0900	H3VU	36.1	75.3	050 / 36	1014.7
25 / 1400	C6VV8	33.5	76.4	050 / 45	1008.7
25 / 1600	C6VV8	33.9	76.1	050 / 40	1008.7
25 / 1800	9V9290	33.9	76.4	020 / 35	1011
25 / 1800	C6VV8	34.3	75.7	020 / 35	1010.6
25 / 2200	C6VV8	35.5	74.8	050 / 35	1011.6
26 / 1200	ELQQ4	33.9	76.6	330 / 35	1003
27 / 0600	WMCS	33.7	67.8	150 / 38	1010.2
27 / 0900	WMCS	33.1	68.4	160 / 38	1009
27 / 1800	V7SX3	37.4	69.8	140 / 40	1002.9
29 / 0200	ZCEK6	43.4	64.3	340 / 35	1003.4
29 / 0600	PBIG	40.9	70.9	010 / 35	1012
29 / 0600	ZCDM6	43.6	64.6	330 / 36	1005.8
29 / 0800	ZCEK6	41.9	66	350 / 40	1008
29 / 1700	VRGP2	35.8	60.1	210 / 55	1014

Table 4. Selected surface observations for Hurricane Maria, 16–30 September 2017.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Antigua and Barbuda									
Automated Weather Observation Systems (AWOS) Sites									
Antigua (17.14 N 61.79W)			19/0900	37	45 (10 m)				
National Ocean Service (NOS) Sites									
Barbuda (BARA9) (17.59N 61.82W)	19/1718	1005.8				0.65		0.7	
Dominica									
International Civil Aviation Organization (ICAO) Sites									
Canefield Airport (TDCF) (15.34N 61.39W)	19/0210	948	19/0140	73 (10 min)	116				17.8
Douglas–Charles Airport (TDPD) (15.55N 61.30W)	19/0240	960	19/0240	130 (10 min)					2.4
Cophall									22.8
Wet Area Belles	19/0230	953	19/0200	56 (10 min)	73				22.0
Salisbury (15.44N 61.44W)									18.5
Pond Casse									14.6
Milton Estate									3.9
Dominican Republic									
ICAO Sites									
Arroyo Barril (MDAB) (19.20N 69.43W)	21/1000	995.8	21/1500	40	74 (5 m)				12.2
Samana El Catey (MDCY) (19.27N 69.73W)	21/0900	992.8	21/1500	34	65 (20 m)				5.9
Punta Cana (MDPC) (18.57N 68.36W)	21/0100	993.0	21/0900	33	57 (19 m)				9.8
Public/Other									
Sabana de la Mar (19.05N 69.38W)	21/1200	996.9	21/1500	16	59 (3 m)				12.9
Guadeloupe									
AWOS Sites									
Guadeloupe (16.27N 61.53W)			19/0830	40	56 (10 m)				
ICAO Sites									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Pointe-a-Pitre Le Raizet Airport (TFFR) (16.26N 61.52W)	19/0400	997.6	19/0500	45	67 (11 m)				10.2
Grand Bourg Les Basses Airport (TFFM) (15.87N 61.27W)	18/2300	996.6	18/2200	41[f]	66 (10 m)				2.1
La Desirade Grande Anse Airport (TFFA) (16.34N 61.00W)	19/0200	1003.6	18/2200	52[f]	67 (26 m)				
Baillif Airport (TFFB) (16.01N 61.74W)			19/0200	50	80 (6 m)				10.4
Gourbeyre Gros-Morne Dole (16.00N 61.67W)			19/0106		88				
Pointe-Noire Bellevue (16.23N 61.78W)			19/0236		86				
North Carolina									
Weatherflow Sites									
KHK Resort (XRTH) (35.58N 75.47W)	27/1750	998.1	27/1655	42	51 (16 m)				
Oregon Inlet CG (XORE) (35.77N 75.53W)	27/0640	999.7	27/1405	41	48 (10 m)				
Jennettes Pier (XJNP) (35.911N 75.59W)	27/1805	1000.8	27/1600	41	48 (18 m)				
Stumpy Point Tower (XSTP) (35.71N 75.77W)			27/1805	39	51 (98 m)				
Pamlico Sound (XPM2) (35.43N 75.83W)	27/0731	997.7	26/1816	36	46 (13 m)				
REAL Slick (XSLK) (35.57N 75.49W)	27/0735	999.3	27/1555	35	47 (6 m)				
Alligator Bridge (XALI) (35.90N 76.01W)	27/0739	1000.8	26/2254	35	46 (12 m)				
Frisco Woods (XFRI) (35.25N 75.63W)	27/0745	999.0	27/0145	35	45 (6 m)				
Hatteras High (XHAT) (35.26N 75.55W)	27/0521	998.2	27/1616	34	44 (22 m)				
Avon Ocean (XAVO) (35.35N 75.50W)	27/0719	998.7	26/2044	34	44 (12 m)				
Ocracoke (XOCR) (35.14N 76.01W)	27/0725	1000.4	26/1640	34	42 (8 m)				
National Data Buoy Center (NDBC) Sites									
Diamond Shoals (41025) (35.01N 75.40W)	27/0650	997.1	27/0550	36 (1 min)	47 (5 m)				
NOS Sites									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
USCG Station Hatteras (HCGN7) (35.21N 75.70W)	27/0700	1000.7	26/2000	36	44 (10 m)	2.85	2.94	2.7	
Duck (DUKN7) (36.18N 75.75W)	27/1818	1001.7	27/1130	38	44 (16 m)	2.11	3.24	1.7	
Oregon Inlet Marina (ORIN7) (35.80N 75.55W)	27/0654	1001.0	27/0724	30	43 (8 m)	1.75	1.92	1.4	
Beaufort (BFTN7) (34.72N 76.67W)	27/0700	1003.7	26/1830	29	41 (9 m)	1.54	2.84	1.4	
Wrightsville Beach (JMPN7) (34.21N 77.79W)	26/2130	1006.4	29/0912	26	29 (15 m)	1.59	3.19	1.4	
Wilmington (WLON7) (34.23N 77.95W)	27/1912	1007.3				1.79		0.9	
Public/Other									
Corbina (35.60N 75.47W)			27/1754	39	51				
Kill Devil Hills (36.01N 75.66W)	27/0644	1003	27/1629	35	36				
Puerto Rico									
Weatherflow Sites									
Isla Culebrita Light (XCUL) (18.31N 65.23W)	20/0839	957.8	20/0844	101	120 (83 m)				
San Juan NAVAID (XJUA) (18.46N 66.13W)			20/1130	79[f]	95 (14 m)				
Gurabo (XGUR) (18.26N 65.99W)	20/1130	943.4	20/1010	70[f]	104 (62 m)				
Del Rey Marina (XREY) (18.29N 65.63W)	20/0700	995.3	20/0840	69[f]	87 (10 m)				
Yabucoa-El Negro (XYAB) (18.05N 65.83W)	20/0931	937.5	20/0906	66[f]	102 (13 m)				
Las Mareas (XMRS) (17.93N 66.16W)			20/1214	94	109 (11 m)				
Puerto Rico Seismic Network Sites									
Yabucoa Harbor (YABP4) (18.06N 65.83W)			20/1124	71[f]	98[f] (6 m)	5.44[f]		5.3[f]	
Fajardo (FRDP4) (18.34N 65.63W)	20/0848	977.4[f]	20/0848	63[f]	85[f] (6 m)	3.17[f]		2.2[f]	
Isabel Segunda, Vieques Island (VQSP4) (18.15N 65.44W)			20/0748	44[f]	89[f] (6 m)	2.86		2.0	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Arecibo (AROP4) (18.48N 66.70W)	20/1536	963.7	20/1342	69	98 (6 m)	2.40		1.9	
NOS Sites									
San Juan, La Puntilla, San Juan Bay (SJNP4) (18.46N 66.12W)	20/1212	975.5[f]	20/0948	42[f]	61[f] (7 m)	2.35[f]	3.18[f]	2.4[f]	
Mona Island (MISP4) (18.09N 67.94W)	20/2012	998.8				2.54	2.81	2.4	
Mayaguez (MGZP4) (18.22N 67.16W)	20/1724	977.1	20/1948	52[f]	68[f] (12 m)	2.56[f]	2.17[f]	1.4[f]	
Culebra (CLBP4) (18.30N 65.30W)	20/0830	983.0				1.56	1.69	1.1	
Esperanza, Viequez Island (ESPP4) (18.09N 65.47W)	20/0630	986.5[f]	20/0630	27[f]	53[f] (11 m)	0.99[f]	1.19[f]	0.8[f]	
Magueyes Island (MGIP4) (17.97N 67.05W)	20/1224	993.4[f]	20/1148	38[f]	56[f] (8 m)	0.40[f]	0.91[f]	0.5[f]	
RAWS Sites									
Camp Santiago (CSAP4) (18.01N 66.29W)			20/1109	55	103 (91 m)				7.56
Cabo Rojo (CRRP4) (18.08N 67.15W)			20/1857	43	70 (32 m)				7.92
Caribbean Integrated Coastal Ocean Observing System (CarICOOS) Buoys									
Vieques (41056) (18.26N 65.46W)	20/0820	977.4	20/0830	54[f]	64 (4 m)				
Ponce (42085) (17.86N 66.52W)	20/1100	983.0	20/1600	51[f]	68 (4 m)				
San Juan (41053) (18.47N 66.10W)	20/1320	981.5	20/1020	51[f]	66 (4 m)				
Public/Other									
Yabucoa (18.04N 65.87W)	20/1009	926.6							
Palmas Del Mar, Humacao (18.08N 65.80W)	20/0947	929.4							
Caguas (CAIP4) (18.23N 66.04W)									37.90
Villalba (TOXP4) (18.13N 66.48W)									27.82
Caguas (BZDP4) (18.23N 66.04W)									23.43
Villalba (VINP4) (18.13N 66.48W)									22.95
Aibonito (AIBP4) (18.14N 66.27W)									22.79

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Coamo (COAP4) (18.08N 66.35W)									19.38
Ciales (VILP4) (18.33N 66.47W)									19.23
Caguas (BZCP4) (18.23N 66.04W)									18.51
Utuado (VIVP4) (18.27N 66.70W)									18.38
Comerio (COMP4) (18.22N 66.22W)									17.50
Juncos 1 S (VALP4) (18.22N 65.93W)									16.86
Yauco (LLYP4) (18.03N 66.86W)									16.73
San Lorenzo (SLGP4) (18.19N 65.97W)									16.52
Bayamon (BAYP4) (18.38N 66.16W)									16.36
Caguas 6 WSW (CAHP4) (18.21N 66.11W)									15.91
San Lorenzo (SLEP4) (18.19N 65.97W)									15.22
Arecibo (ARFP4) (18.45N 66.73W)									14.71
Caguas 1 NE (CAMP4) (18.23N 66.04W)									13.56
Cidra (DRAP4) (18.17N 66.16W)									12.17
Aguas Buenas (BZAP4) (18.25N 66.11W)									12.15
Ponce (PRTP4) (17.98N 66.61W)									11.65
San German (MAOP4) (18.08N 67.05W)									11.12
Ponce (PRNP4) (17.98N 66.61W)									10.47
Utuado (UTHP4) (18.27N 66.70W)									10.11
Orocovis 6 SW (OROP4) (18.21N 66.48W)									9.76
Patillas 1 NE (PASP4) (18.02N 66.02W)									9.42
Juncos 7 ENE (GUSP4) (18.25N 65.83W)									9.3
Guanica (GCAP4) (17.97N 66.93W)									7.12

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Lares (LARP4) (18.29N 66.88W)									6.91
Naguabo (NGIP4) (18.21N 65.74W)									6.31
Caguas 4 NW (BZBP4) (18.27N 66.10W)									6.14
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Juncos 0.3 WSW (PR-JN-1) (18.22N 65.92W)									25.0
Trujillo Alto 0.8 WSW (PR-TR-2) (18.36N 66.03W)									15.43
Rincon 2.8 SE (PR-RN-4) (18.32N 67.22W)									11.78
Juana Diaz 2.9 SW (PR-JD-2) (18.03N 66.54W)									8.78
Lajas 2.2 E (PR-LJ-2) (18.04N 67.03W)									8.52
Cabo Rojo 0.8 SE (PR-CR-1) (18.08N 67.14W)									7.69
Aguadilla 5.5 NNE (PR-AL-3) (18.51N 67.11W)									6.21
Fajardo 0.4 NE (PR-FJ-2) (18.34N 65.65W)									5.7
USGS High Water Marks									
Arrayao, Punta Santiago (PRHUM23681) (18.17N 65.74W)							9.52	4.9	
Playa de Naguabo (PRHUM23708) (18.19N 65.73W)							8.76	1.4	
Playa de Naguabo (PRHUM23697) (18.18N 65.71W)							8.75	2.9	
Playa de Guayanes (PRYAB20635) (18.06N 65.82W)							8.70		
Punta Santiago (PRHUM23667) (18.16N 65.75W)							8.48	5.1	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Marina Puerto Chico (PRFAJ20587) (18.35N 65.64W)							5.51		
Playa Medio Mundo (PRCEI22309) (18.27N 65.63W)							5.23	2.5	
USGS Storm Tide Sensors									
Ocean Park Beach, San Juan (PRSAN20648) (18.45N 66.04W)							7.95		
Villa Pesquera (PRMAU22311) (17.99N 65.89W)							4.26		
Juana Diaz (PRJUA22307) (17.99N 66.48W)							4.24		
Playa Medio Mundo (PRCEI22309) (18.27N 65.63W)							4.21		
Villa Pesquera Beach of Patillas (PRPAT22312) (17.98N 65.99W)							4.13		
Malecon de Arroyo (PRARR22313) (17.96N 66.06W)							3.93		
Jobos Bay (PRSAL22314) (17.95N 66.23W)							3.84		
Marina Puerto Chico (PRFAJ20587) (18.35N 65.64W)							3.66		
Villa Pesquera Santa Isabel (PRSAN22316) (17.96N 66.41W)							3.62		
Dorado Public Beach (PRDOR20633) (18.48N 66.28W)							3.24		
Playa de Ponce (PRPON22310) (17.98N 66.62W)							2.69		
Saint Martin									
Cul-de-Sac (18.05 N 63.06W)			19/0316	38[f]	48				
St. Eustatius									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
AWOS Sites									
St. Eustatius (17.49 N 62.98W)			19/1455	37	52 (10 m)				
Turks and Caicos Islands									
Public/Other									
Grace Bay (21.80N 72.18W)			22/0930	41	48				
U.S. Virgin Islands									
CarICOOS Buoys									
South of St. John (41052) (18.25N 64.76W)	20/0700	992.5	20/0830	41	56 (4 m)				
NOS Sites									
Lime Tree Bay, St. Croix (LTBV3) (17.70N 64.75W)	20/0342	976.1[f]	20/0330	60[f]	89[f] (10 m)	2.85[f]	3.17[f]	2.8[f]	
Christiansted Harbor, St. Croix (CHSV3) (17.75N 64.70W)	20/0518	978.4	20/0142	43	65 (8 m)	2.27	2.36	2.0	
Lameshur Bay, St. John (LAMV3) (18.32N 64.72W)	20/0612	998.2				1.48	1.61	1.2	
Weatherflow Sites									
Sandy Point NWR, St. Croix (XCRX) (17.68N 64.90W)	20/0538	950.1	20/0618	93	119 (20 m)				
Rupert Rock, St. Thomas (XRUP) (18.33N 64.93W)	20/0701	993.6	20/0201	39[f]	56 (5 m)				
Public/Other									
Christiansted, St. Croix (CVAV3) (17.74N 64.62W)			20/0613	86	118				5.03
Virginia									
Weatherflow Sites									
Chesapeake Light Tower (XCLT) (36.90N 75.71W)	27/1951	998.8	27/1816	36	42 (41 m)				
NDBC Buoy Sites									
Virginia Beach (44014) (36.61N 74.84W)	27/1750	998.5	27/1559	37 (1 min)	43 (5 m)				
NOS Sites									

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Sewells Point (SWPV2) (36.94N 76.33W)	27/2030	1005.8				1.94	2.83	1.7	
Chesapeake Bay Bridge Tunnel (CHBV2) (37.03N 76.08W)	27/2018	1005.0	26/1900	31	36	1.87		1.6	
Wachapreague (WAHV2) (37.61N 75.69W)	27/2042	1004.9	27/1742	28	35 (9 m)	1.96	3.22	1.4	
Kiptopeke (KPTV2) (37.17N 75.99W)			27/1624	21	27 (10 m)	1.66	2.37	1.3	
Offshore									
NDBC Buoy Sites									
Caribbean Valley (42060) (16.41N 63.19W)	19/1500	955.7	19/1442	74 (1 min)	82 (4 m)				
NE Bahamas (41047) (27.52N 71.53W)	24/0630	987.4	24/0154	58 (1 min)	74 (4 m)				
South Hatteras (41002) (31.76N 74.84W)	26/0250	992.4	25/2350	41 (5 min)	52 (5 m)				
East Bahamas (41046) (23.83N 68.42W)	22/2210	1004.9	22/2055	37 (1 min)	45 (4 m)				
West Bermuda (41048) (31.86N 69.59W)	25/2000	1007.0	25/0808	35 (1 min)	39 (5 m)				

[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 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 the North American Vertical Datum of 1988 (NAVD88) in the continental United States, the Puerto Rico Vertical Datum of 2002 (PRVD02) in Puerto Rico, and the Virgin Islands Vertical Datum of 2009 (VIVD09) in the U.S. Virgin Islands.
[e] Estimated inundation is the maximum height of water above ground. For tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.
[f] Incomplete Data

Table 5. Number of hours in advance of the formation of Maria associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	60	60
Medium (40%-60%)	30	54
High (>60%)	18	42

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Maria. Mean errors for the previous 5-yr period 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	**12.9**	**20.5**	**26.8**	**35.8**	**58.3**	**85.0**	**122.2**
OCD5	29.3	69.9	112.2	149.2	191.9	214.2	225.2
Forecasts	55	53	51	49	45	41	37
OFCL (2012-16)	24.9	39.6	54.0	71.3	105.8	155.4	208.9
OCD5 (2012-16)	47.3	103.9	167.8	230.3	343.1	442.6	531.0

Table 6b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Maria. 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 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	12.6	19.5	24.6	33.9	54.3	85.1	126.6
OCD5	28.8	69.1	107.6	135.1	163.6	210.7	220.2
GFSI	15.2	24.2	30.8	35.4	**47.8**	95.6	130.5
HWFI	21.0	35.2	44.9	43.7	55.9	97.5	163.4
HMNI	18.4	30.1	37.3	44.1	61.4	**81.4**	**107.6**
EGRI	15.4	28.9	41.7	54.8	73.7	102.1	134.8
EMXI	**12.4**	20.7	28.2	42.1	84.3	138.1	177.8
CMCI	15.3	25.7	37.2	46.9	58.9	100.4	174.6
CTCI	15.8	27.7	39.1	49.9	81.5	119.4	157.6
TCON	14.9	25.0	33.0	38.3	**49.3**	**79.0**	**99.0**
TVCA	13.5	21.9	29.0	35.8	54.3	**81.3**	**106.2**
TVCX	12.7	20.8	28.4	35.3	57.6	85.3	**112.6**
GFEX	**12.5**	20.1	25.7	**33.1**	58.3	94.3	135.9
HCCA	**12.2**	20.9	28.1	35.0	58.1	**84.7**	**107.0**
FSSE	14.5	23.0	30.8	36.7	62.6	**84.7**	**111.9**
AEMI	15.7	24.1	31.5	35.9	**51.9**	108.2	152.4
TABS	36.0	53.5	50.6	61.5	62.5	95.6	144.0
TABM	20.4	39.7	50.6	42.2	62.8	119.4	137.9
TABD	20.4	39.7	50.6	42.2	62.8	119.4	137.9
Forecasts	47	45	43	41	38	37	33

Table 7a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Maria. Mean errors for the previous 5-yr period 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	6.6	10.6	13.0	14.5	**12.2**	**8.8**	**8.1**
OCD5	8.5	13.7	17.3	18.7	15.5	12.2	14.6
Forecasts	55	53	51	49	45	41	37
OFCL (2012-16)	5.5	8.2	10.5	12.0	13.4	14.0	14.5
OCD5 (2012-16)	7.1	10.5	13.0	15.1	17.4	18.2	20.6

Table 7b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Maria. 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 7a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	6.7	11.0	13.8	15.2	12.0	8.4	7.7
OCD5	8.5	14.0	17.6	18.5	14.1	11.2	14.2
HWFI	7.2	**10.4**	**13.1**	**14.3**	**11.0**	8.6	8.8
HMNI	7.6	12.1	14.0	**14.7**	14.4	12.8	14.6
DSHP	8.4	14.7	19.1	20.4	16.1	14.1	15.0
LGEM	7.3	12.2	15.7	16.7	**10.3**	**7.6**	8.4
ICON	7.0	11.6	15.1	15.8	**10.1**	**7.1**	9.0
IVCN	7.1	11.7	15.3	15.9	**9.9**	**5.4**	**7.3**
CTCI	8.6	12.6	17.2	18.1	13.6	**7.6**	8.5
GFSI	9.9	16.7	21.4	22.3	18.9	15.7	13.5
EMXI	10.6	17.5	22.8	25.5	24.9	23.1	27.5
HCCA	7.1	11.5	14.8	**15.0**	**9.9**	**3.7**	**7.3**
FSSE	**6.2**	**9.3**	**11.8**	**12.5**	**9.4**	**6.1**	**4.5**
Forecasts	49	47	45	43	40	38	35

Table 8a. Wind watch and warning summary for Hurricane Maria, 16–30 September 2017.

Date/Time (UTC)	Action	Location
16 / 1500	Tropical Storm Watch issued	St. Lucia
16 / 1500	Tropical Storm Watch issued	Martinique
16 / 1500	Tropical Storm Watch issued	Guadeloupe
16 / 1500	Tropical Storm Watch issued	Dominica
16 / 1800	Tropical Storm Watch issued	Barbados
16 / 1800	Tropical Storm Watch issued	St. Vincent/Grenadines
16 / 2100	Hurricane Watch issued	Antigua/Barbuda/St. Kitts/Nevis/Montserrat
17 / 0000	Tropical Storm Watch changed to Hurricane Watch	Guadeloupe
17 / 0300	Hurricane Watch issued	Saba/St. Eustatius
17 / 0300	Hurricane Watch issued	St. Maarten
17 / 0300	Hurricane Watch issued	Anguilla
17 / 0900	Tropical Storm Watch changed to Hurricane Watch	Dominica
17 / 1200	Hurricane Watch issued	St. Martin/St. Barthelemy
17 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	St. Lucia
17 / 1500	Hurricane Watch changed to Hurricane Warning	Dominica
17 / 1800	Tropical Storm Watch changed to Tropical Storm Warning	Martinique
17 / 1800	Hurricane Watch changed to Hurricane Warning	Guadeloupe
17 / 2100	Tropical Storm Warning issued	Antigua/Barbuda
17 / 2100	Tropical Storm Warning issued	Saba/St. Eustatius
17 / 2100	Hurricane Watch discontinued	Antigua/Barbuda/St. Kitts/Nevis/Montserrat
17 / 2100	Hurricane Watch issued	U.S. Virgin Islands
17 / 2100	Hurricane Watch issued	British Virgin Islands
17 / 2100	Hurricane Warning issued	St. Kitts/Nevis/Montserrat

Date/Time (UTC)	Action	Location
18 / 0000	Tropical Storm Warning changed to Hurricane Warning	Martinique
18 / 0900	Hurricane Watch issued	Puerto Rico/Vieques/Culebra
18 / 1200	Tropical Storm Warning changed to Hurricane Warning	St. Lucia
18 / 1200	Tropical Storm Warning issued	St. Maarten
18 / 1500	Hurricane Watch changed to Hurricane Warning	U.S. Virgin Islands
18 / 1500	Hurricane Watch changed to Hurricane Warning	British Virgin Islands
18 / 1500	Tropical Storm Warning issued	Anguilla
18 / 1800	Tropical Storm Watch discontinued	Barbados
18 / 2100	Hurricane Watch changed to Hurricane Warning	Puerto Rico/Vieques/Culebra
18 / 2100	Hurricane Warning changed to Tropical Storm Warning	St. Lucia
18 / 2100	Tropical Storm Watch issued	Puerto Plata to Northern DR/Haiti Border, Dominican Republic
18 / 2100	Hurricane Watch issued	Isla Saona to Puerto Plata, Dominican Republic
19 / 0000	Hurricane Warning changed to Tropical Storm Warning	Martinique
19 / 1200	Tropical Storm Watch discontinued	St. Vincent/Grenadines
19 / 1200	Tropical Storm Warning discontinued	St. Lucia
19 / 1800	Tropical Storm Watch changed to Tropical Storm Warning	Puerto Plata to Northern DR/Haiti Border, Dominican Republic
19 / 1800	Hurricane Warning changed to Tropical Storm Warning	Guadeloupe
19 / 1800	Tropical Storm Warning discontinued	Martinique
19 / 1800	Tropical Storm Warning issued	Cabo Engano to Punta Palenque, Dominican Republic
19 / 1800	Hurricane Watch modified to	Isla Saona to Cabo Engano, Dominican Republic

Date/Time (UTC)	Action	Location
19 / 1800	Hurricane Warning issued	Cabo Engano to Puerto Plata, Dominican Republic
19 / 2100	Tropical Storm Warning discontinued	Antigua/Barbuda
19 / 2100	Hurricane Watch issued	Turks and Caicos Islands/Southeastern Bahamas
19 / 2100	Hurricane Warning discontinued	Dominica
20 / 0000	Tropical Storm Warning discontinued	Anguilla
20 / 0000	Hurricane Watch discontinued	Anguilla
20 / 0000	Hurricane Warning discontinued	St. Kitts/Nevis/Montserrat
20 / 0600	Tropical Storm Warning changed to Hurricane Watch	Saba/St. Eustatius
20 / 0600	Tropical Storm Warning issued	Saba
20 / 0900	Hurricane Watch changed to Hurricane Warning	Turks and Caicos Islands/Southeastern Bahamas
20 / 0900	Tropical Storm Warning discontinued	Guadeloupe
20 / 0900	Hurricane Watch discontinued	Saba/St. Eustatius
20 / 1200	Hurricane Watch changed to Tropical Storm Warning	St. Martin/St. Barthelemy
20 / 1500	Tropical Storm Warning discontinued	Saba
20 / 1500	Tropical Storm Warning discontinued	St. Maarten
20 / 1500	Tropical Storm Warning discontinued	St. Martin/St. Barthelemy
20 / 1500	Hurricane Watch discontinued	St. Maarten
20 / 2100	Hurricane Warning discontinued	U.S. Virgin Islands
20 / 2100	Hurricane Warning discontinued	British Virgin Islands
21 / 0300	Hurricane Warning discontinued	Puerto Rico/Vieques/Culebra
21 / 1200	Tropical Storm Watch issued	Central Bahamas
21 / 1500	Tropical Storm Warning modified to	Cabo Engano to Andres/Boca Chica, Dominican Republic
21 / 1500	Hurricane Watch discontinued	All

Date/Time (UTC)	Action	Location
21 / 2100	Tropical Storm Warning discontinued	Cabo Engano to Andres/Boca Chica, Dominican Republic
22 / 1200	Tropical Storm Watch changed to Tropical Storm Warning	Central Bahamas
22 / 1500	Tropical Storm Warning discontinued	Puerto Plata to Northern DR/Haiti Border, Dominican Republic
22 / 1500	Hurricane Warning discontinued	Cabo Engano to Puerto Plata, Dominican Republic
22 / 2100	Hurricane Warning changed to Tropical Storm Warning	Turks and Caicos Islands/Southeastern Bahamas
23 / 0900	Tropical Storm Warning discontinued	All
24 / 2100	Tropical Storm Watch issued	Surf City to North Carolina/Virginia Border
24 / 2100	Tropical Storm Watch issued	Pamlico Sound
24 / 2100	Tropical Storm Watch issued	Albemarle Sound
25 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Pamlico Sound
25 / 0900	Tropical Storm Watch changed to Tropical Storm Warning	Albemarle Sound
25 / 0900	Tropical Storm Watch modified to	Duck to North Carolina/Virginia Border
25 / 0900	Tropical Storm Warning issued	Cape Lookout to Duck
25 / 2100	Tropical Storm Watch discontinued	All
25 / 2100	Tropical Storm Warning discontinued	Cape Lookout to Duck
25 / 2100	Tropical Storm Warning issued	Bogue Inlet to North Carolina/Virginia Border
27 / 1500	Tropical Storm Warning modified to	Ocracoke Inlet to North Carolina/Virginia Border
27 / 2100	Tropical Storm Warning modified to	Cape Hatteras to North Carolina/Virginia Border
28 / 0000	Tropical Storm Warning discontinued	All

Table 8b. Storm surge watch and warning summary for Hurricane Maria, 16–30 September 2017. Note: These are only issued for the Gulf and Atlantic coasts of the continental United States.

Date/Time (UTC)	Action	Location
24 / 2100	Storm Surge Watch issued	Cape Lookout to Duck, North Carolina
26 / 1500	Storm Surge Watch changed to Storm Surge Warning	Ocracoke Inlet to Cape Hatteras
27 / 1500	Storm Surge Watch discontinued	west of Ocracoke Inlet
27 / 2100	Storm Surge Watch discontinued	All
27 / 2100	Storm Surge Warning discontinued	All

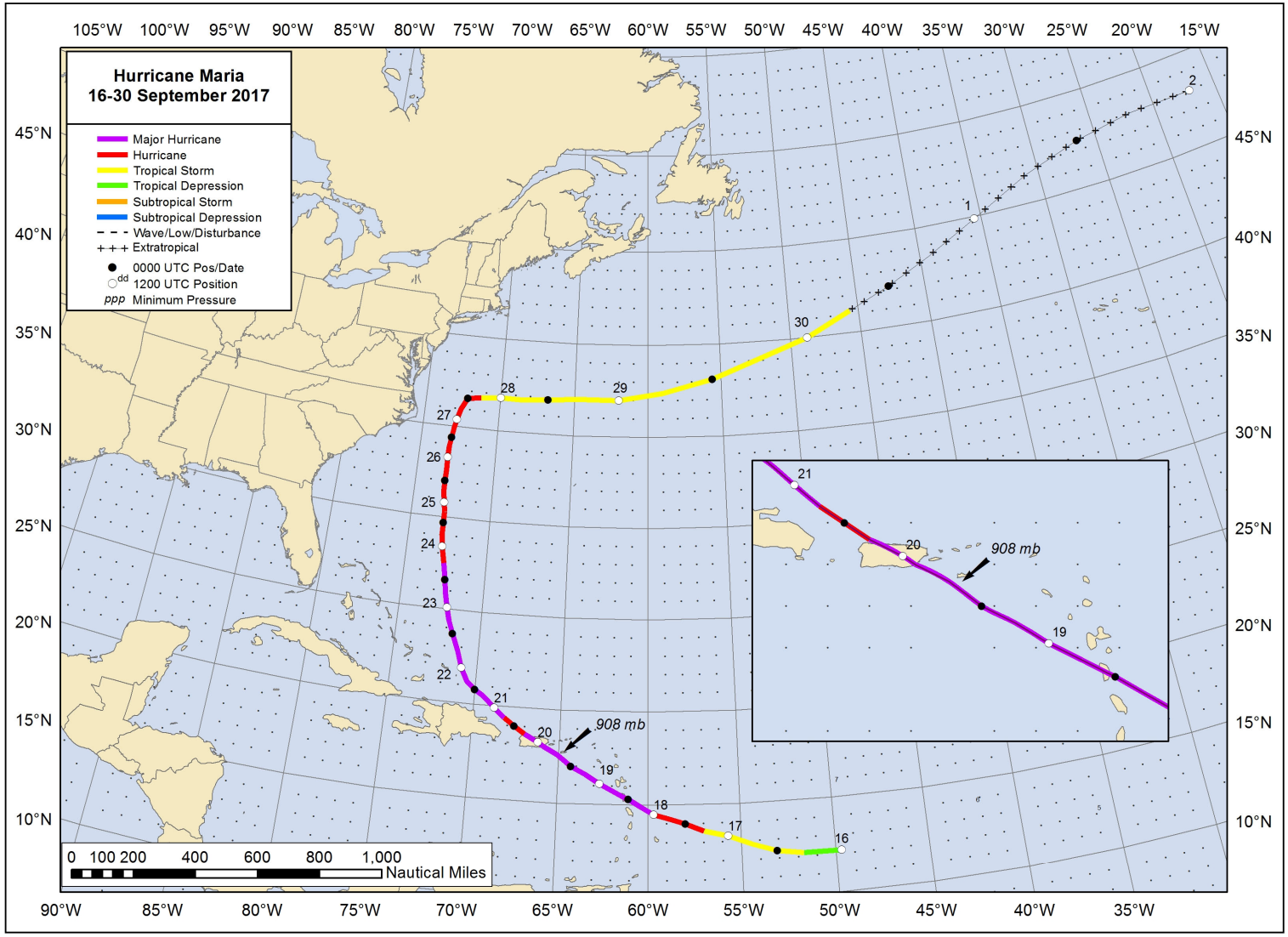

Figure 1. Best track positions for Hurricane Maria, 16–30 September 2017. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

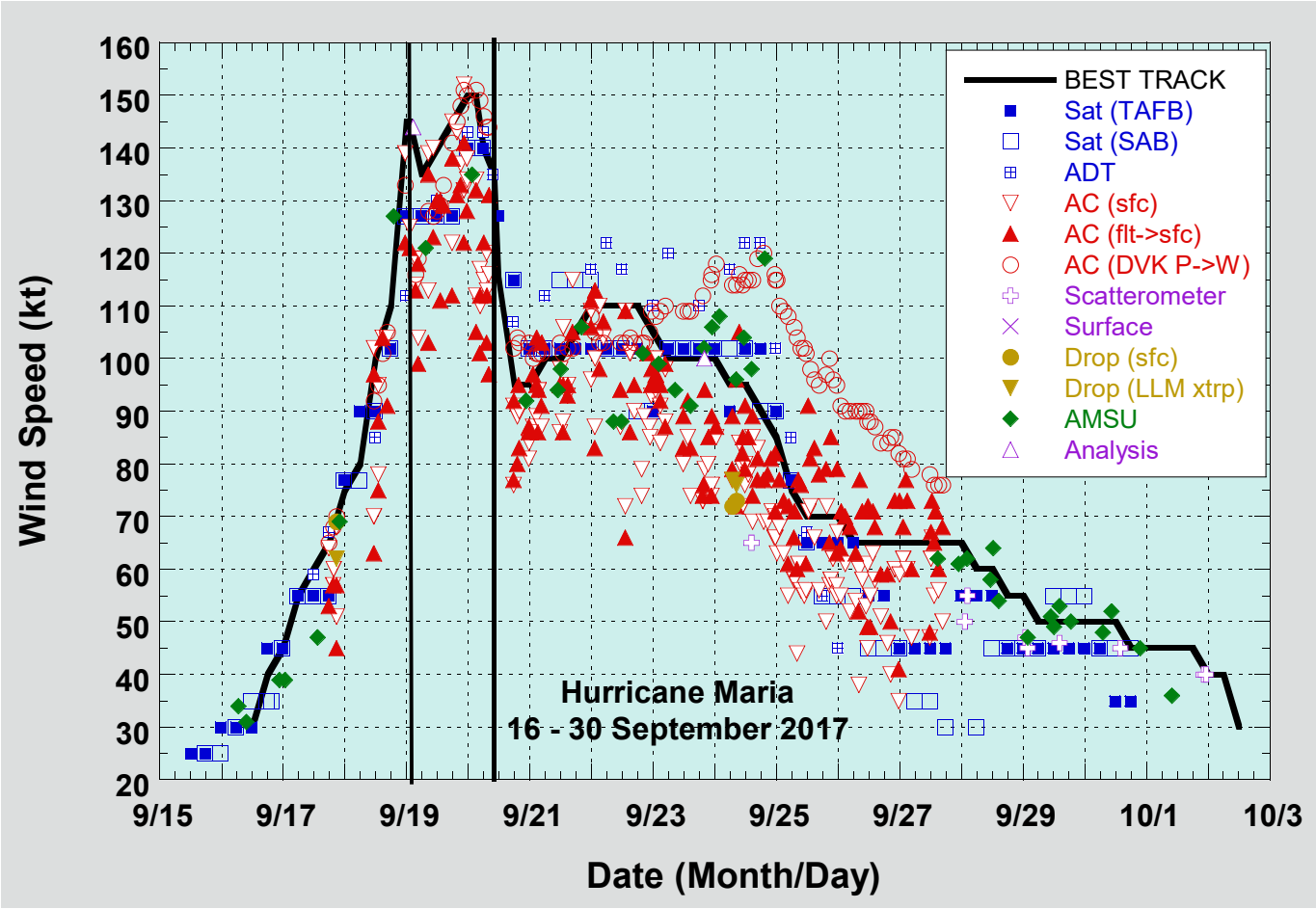

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Maria, 16–30 September 2017. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. 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). Advanced Dvorak Technique estimates represent the Current Intensity at 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 lines correspond to landfalls.

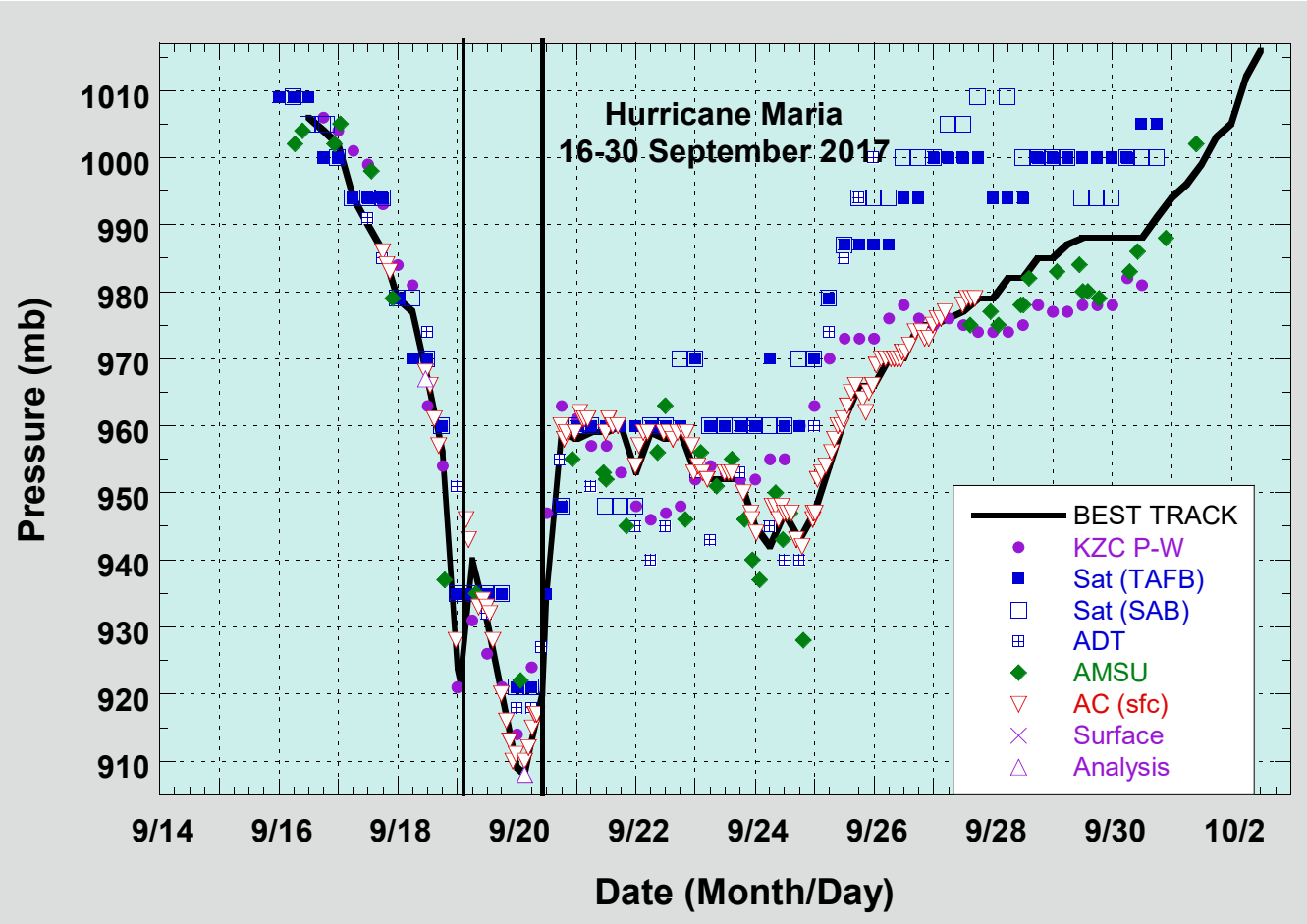

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Maria, 16–30 September 2017. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

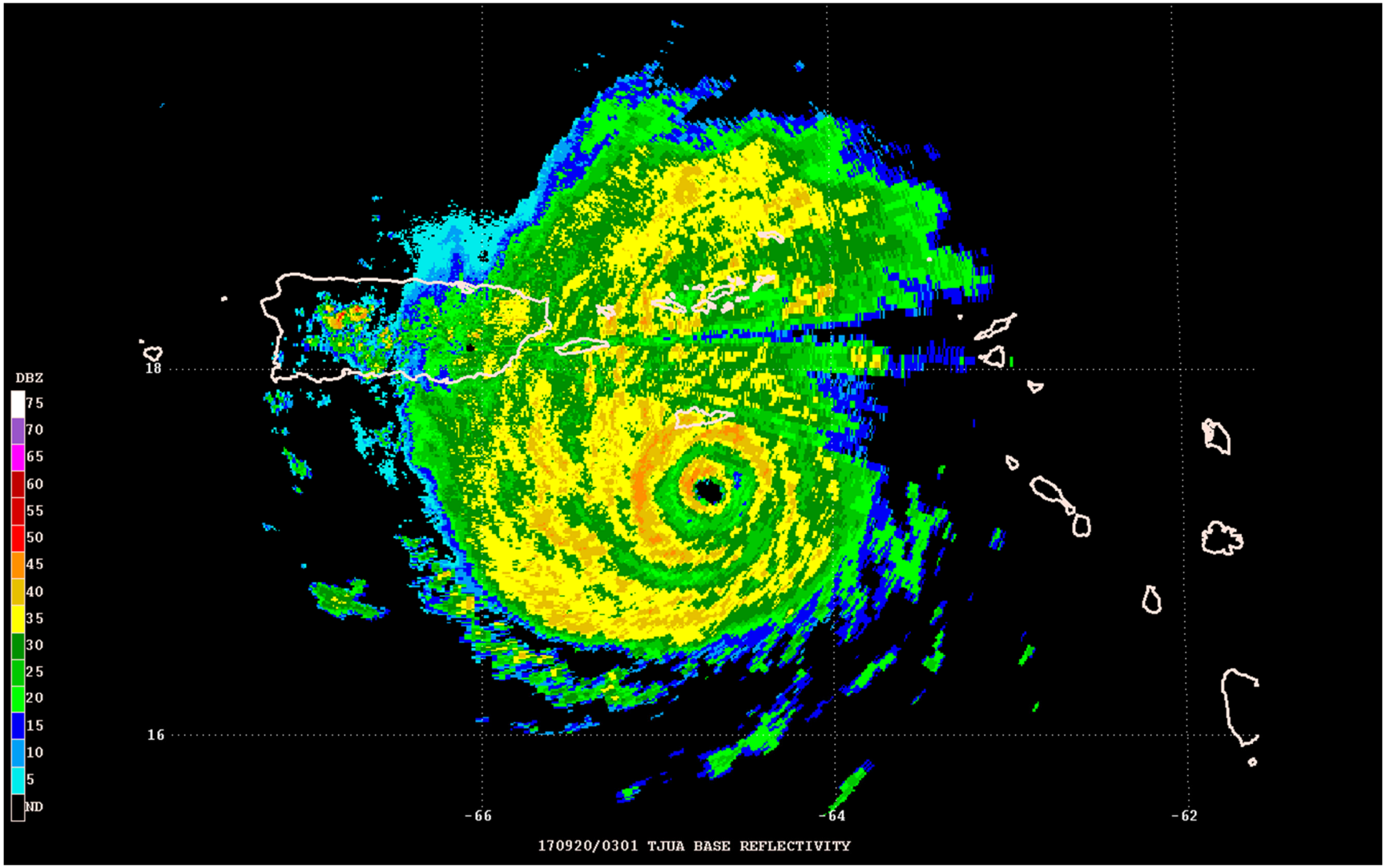

Figure 4a. San Juan WSR-88D radar image of Hurricane Maria near peak intensity at 0301 UTC 20 September, showing the beginning of an eyewall replacement.

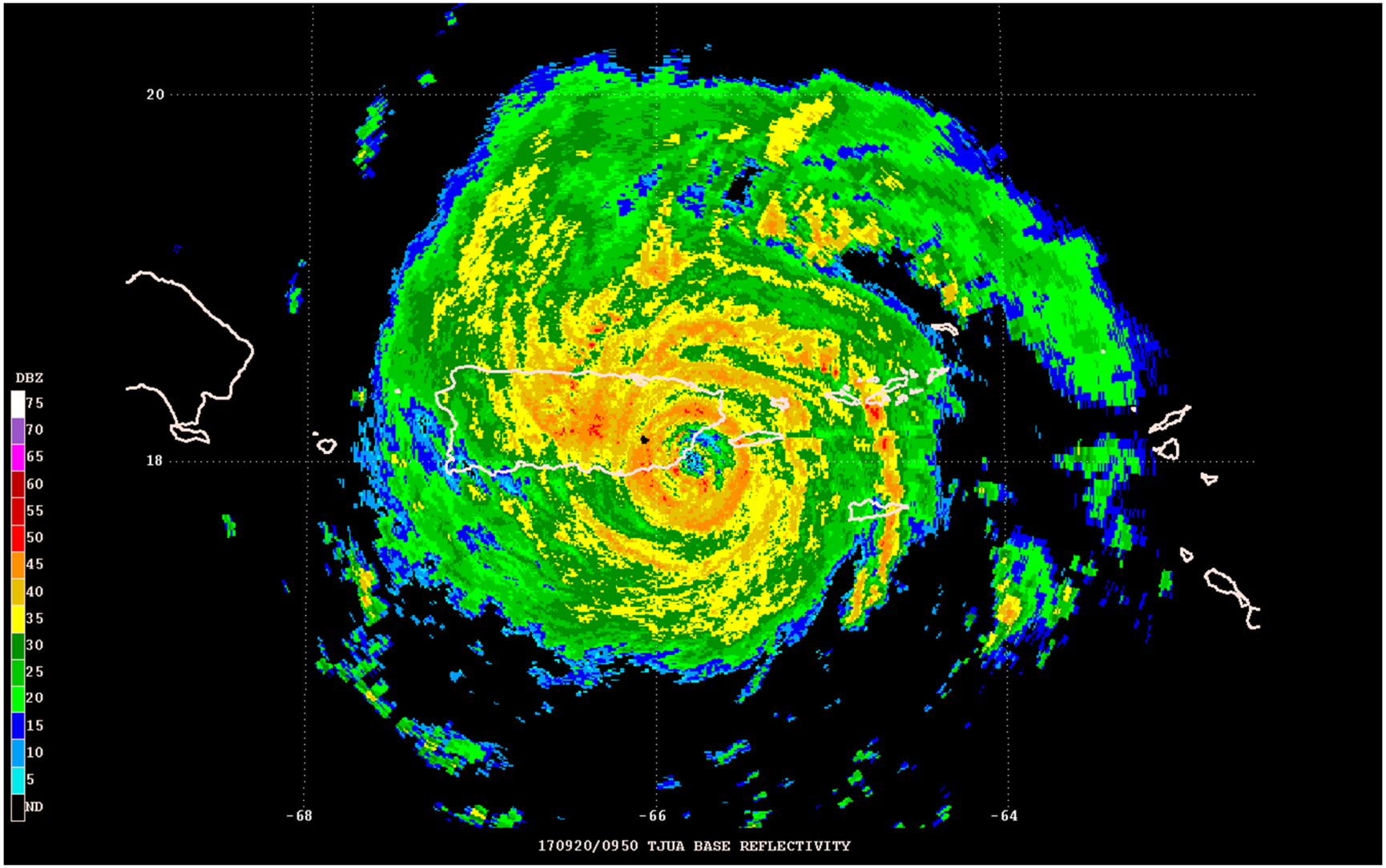

Figure 4b. San Juan WSR-88D radar image of Hurricane Maria at 0950 UTC 20 September, just before landfall in Puerto Rico, showing the more dominant outer eyewall. This was the last image from the radar before it was destroyed.

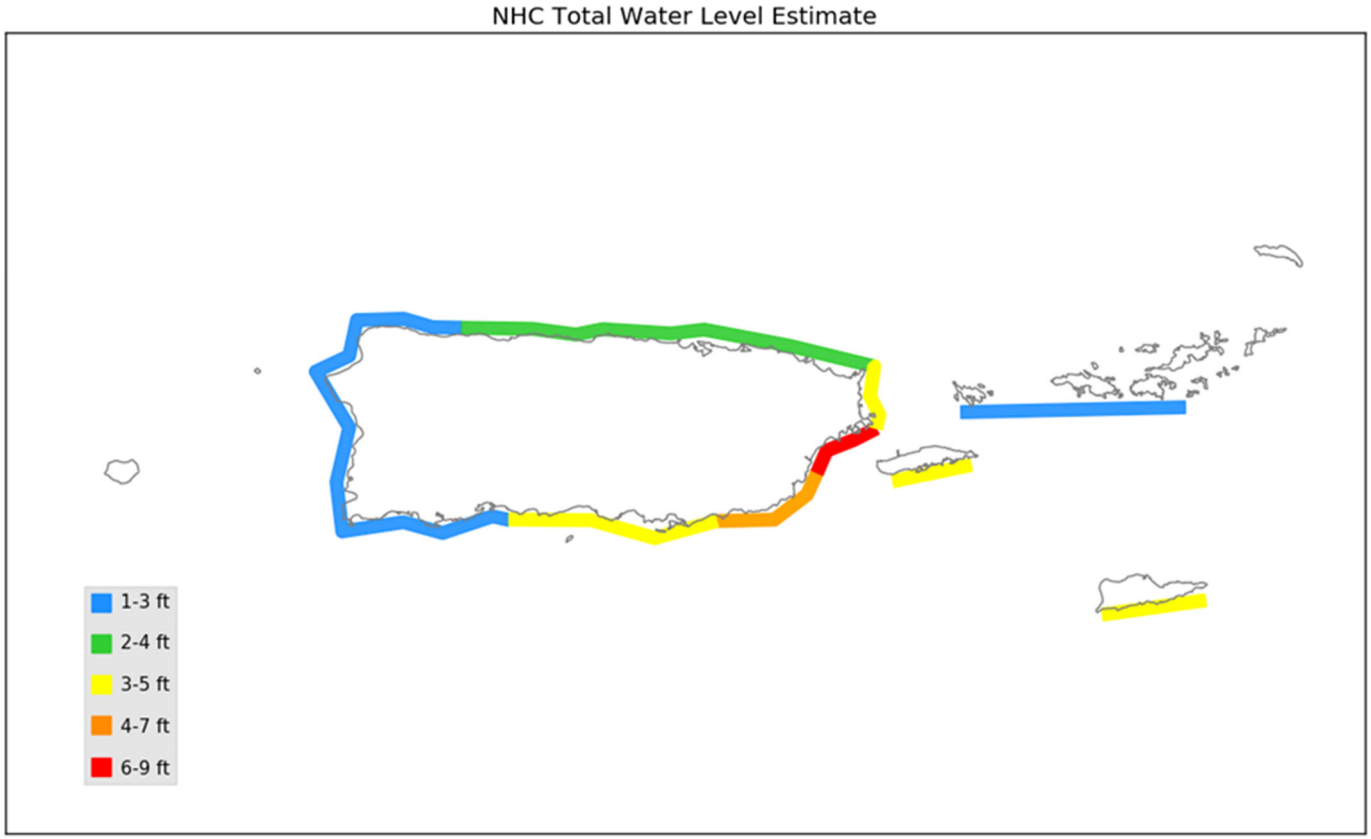

Figure 5. Estimated storm surge inundation (feet above ground level) based on an analysis of water level observations along the coasts of Puerto Rico and the U.S. Virgin Islands from Hurricane Maria. Image courtesy of the NHC Storm Surge Unit.

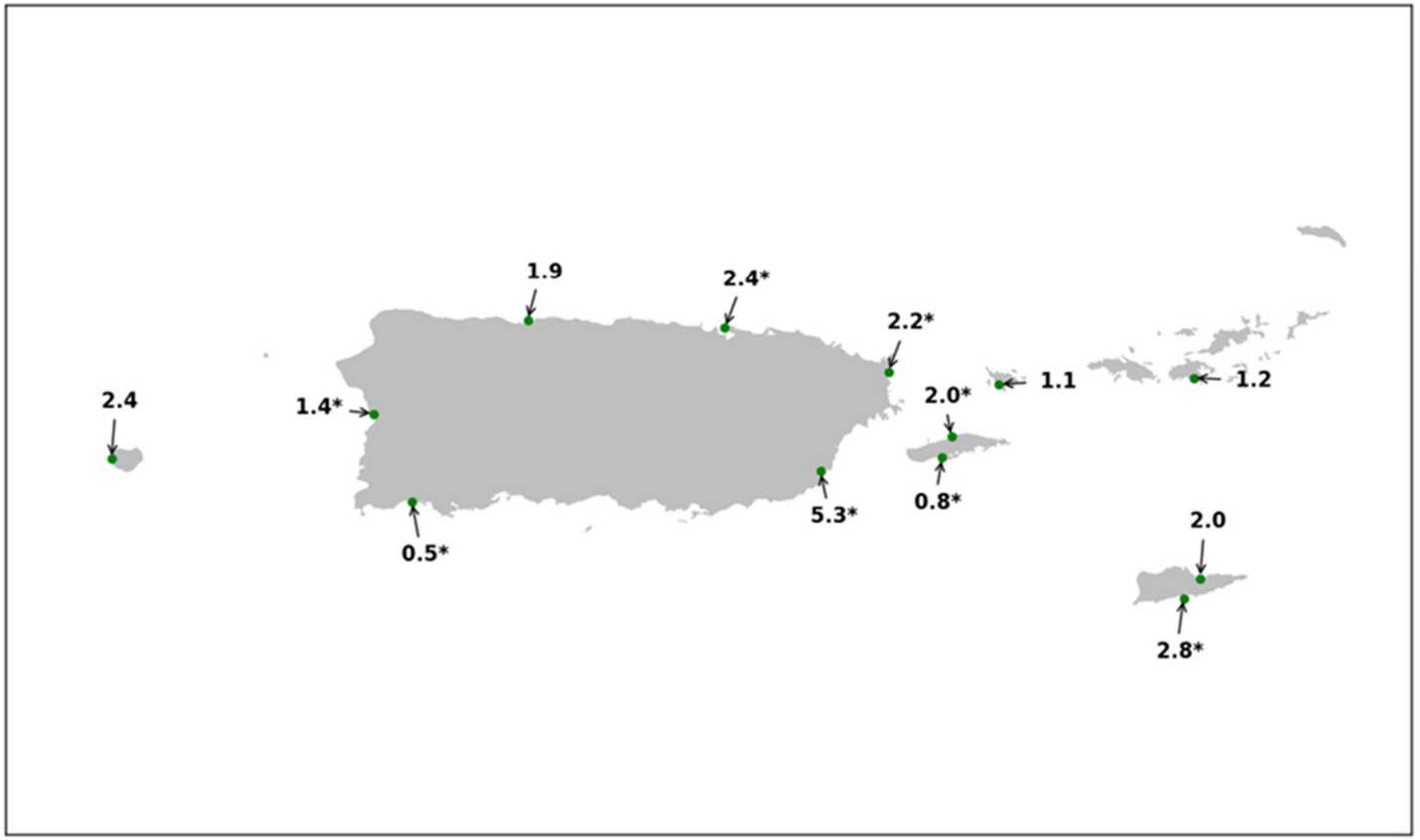

Figure 6. Maximum water levels (feet) measured from tide gauges along the coasts of Puerto Rico and the U.S. Virgin Islands during Hurricane Maria. Water levels are referenced above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. Asterisks denote incomplete data. Image courtesy of the NHC Storm Surge Unit.

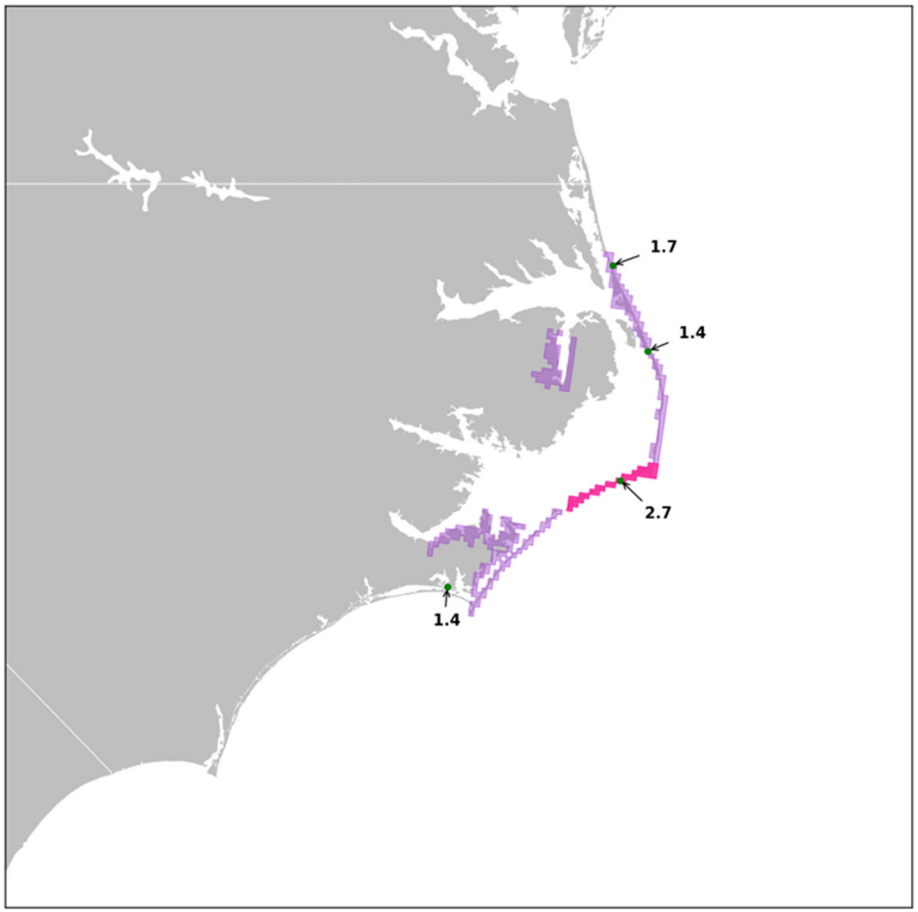

Figure 7. Maximum water levels (feet) measured from tide gauges along the coast of North Carolina during Hurricane Maria and areas covered by storm surge warnings (magenta) and watches (lavender). Water levels are referenced above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. Image courtesy of the NHC Storm Surge Unit.

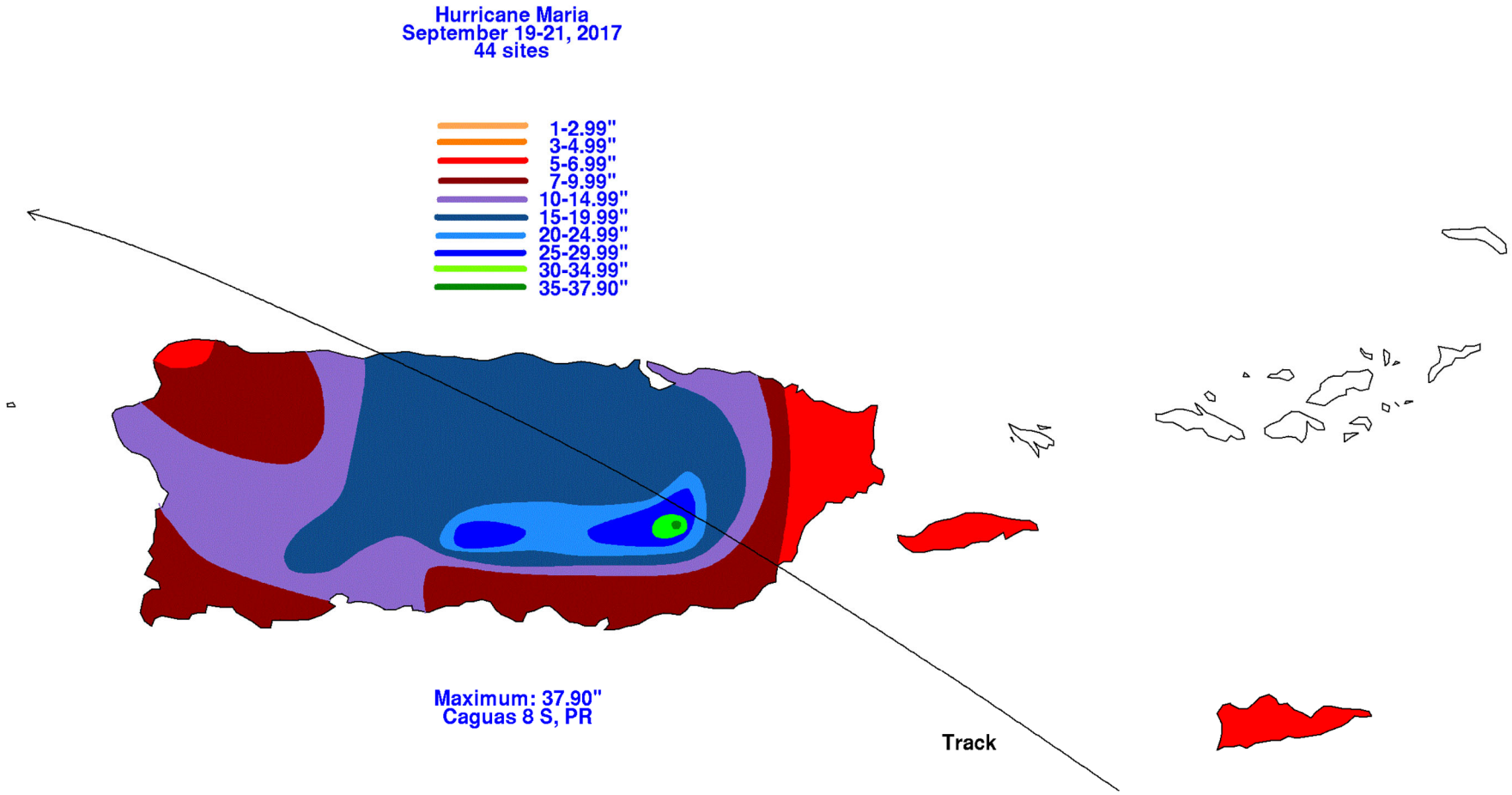

Figure 8. Storm total rainfall (inches) from Hurricane Maria. Figure courtesy of David Roth, NOAA Weather Prediction Center.

Figure 9. Maria's damage in Dominica. Photo credits, clockwise from upper left: WIC News, responsibletravel.com, AFP/Getty Images, Tomás Ayuso/IRIN.

Figure 10. The remnants of the San Juan WSR-88D radar after its destruction by Hurricane Maria. Photo credit: WFO San Juan.

Figure 11. Maria's damage in Puerto Rico. Damage to St. Croix is shown in the lower right panel. Photo credits, clockwise from upper left: U.S. Air Force, VOA News, Reuters/Jonathan Drake, Hector Retamal/AFP/Getty Images.

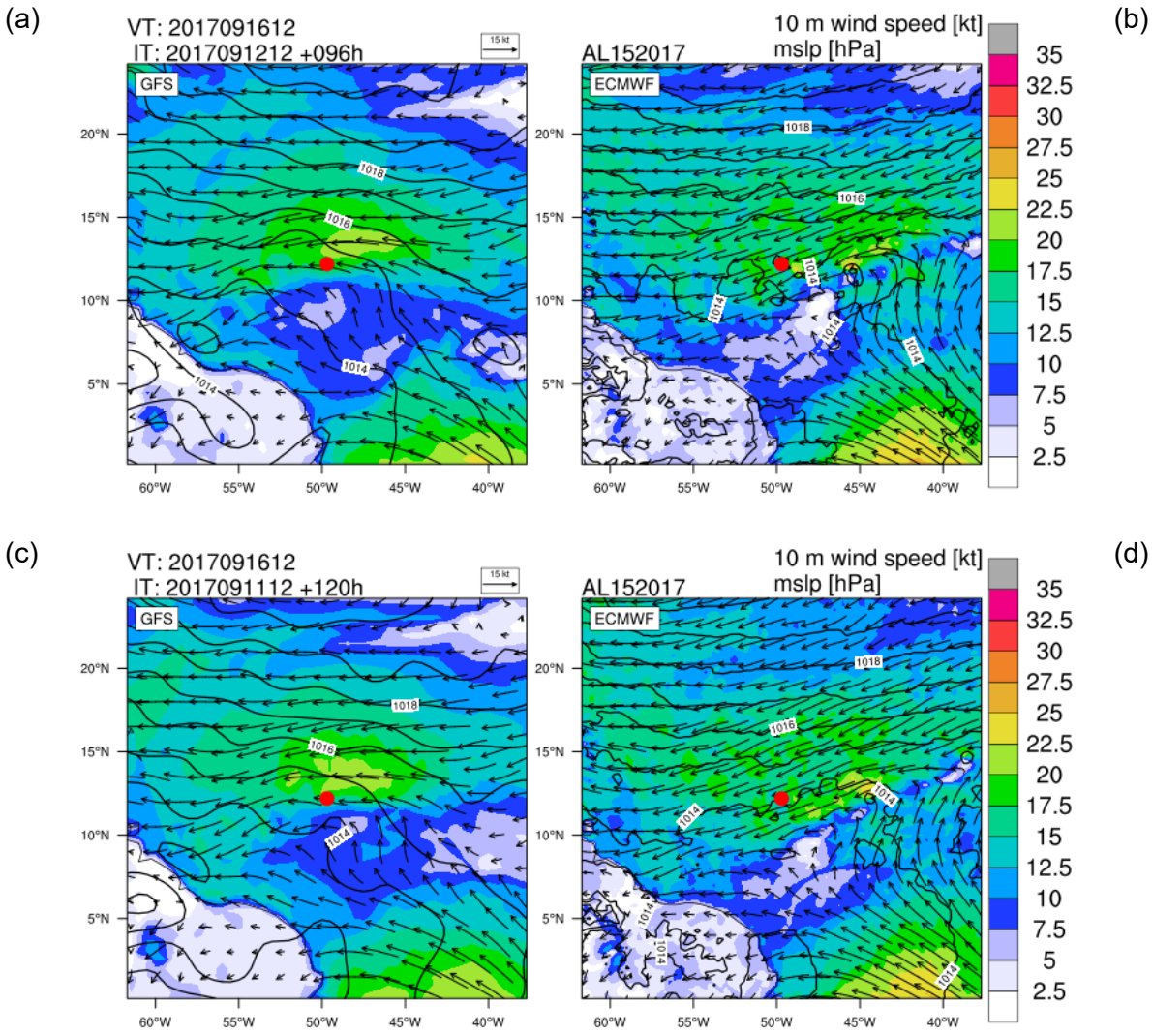

Figure 12. Mean sea-level pressure (black contours, 1-hPa intervals) and 10-m winds (shading and vectors) from (a,c) GFS and (b,d) ECMWF forecasts valid at the time of genesis for Hurricane Maria (1200 UTC September 16). Panels (a) and (b) correspond to 96-h forecasts and (c) and (d) are 120-h forecasts. Red dots indicate the location of Maria's center at the time of genesis.

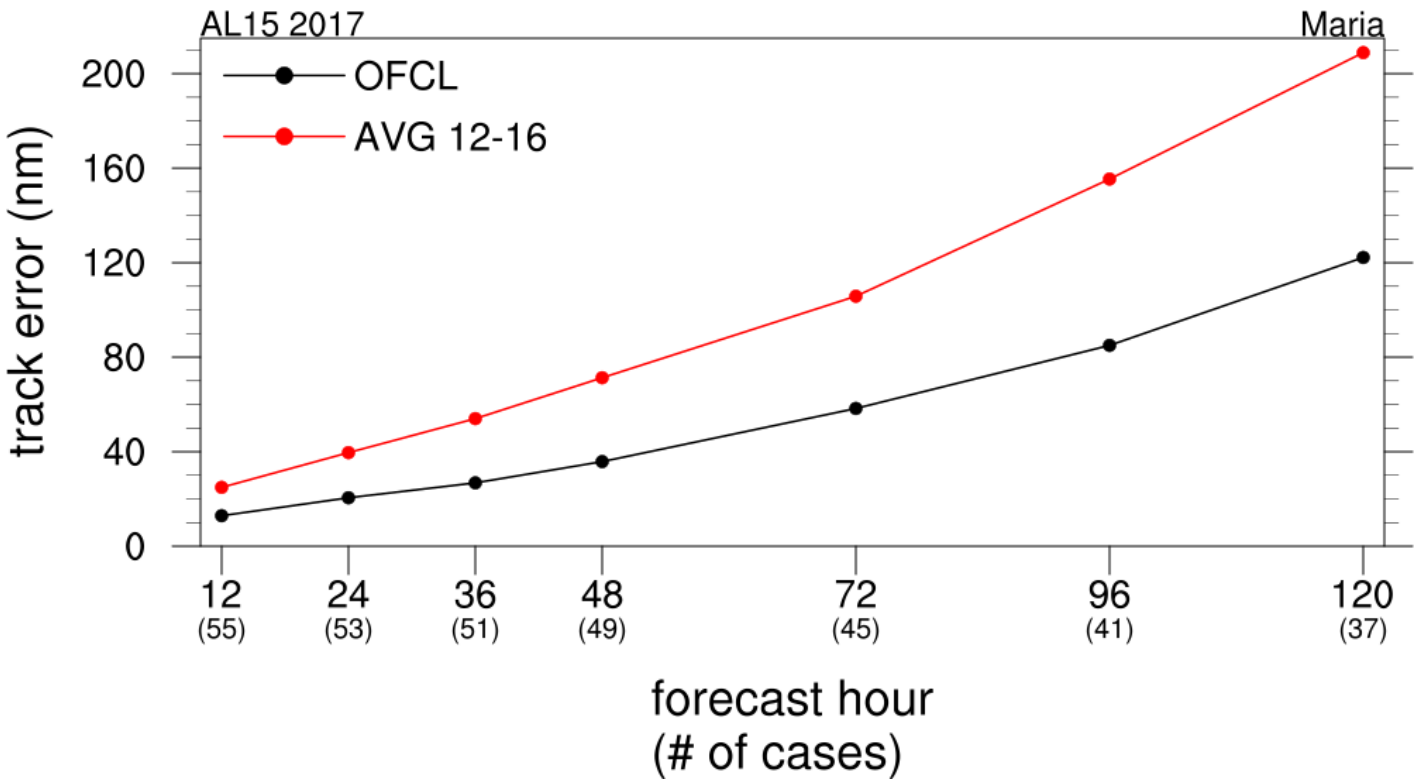

Figure 13. Mean official track forecast errors for Maria (black) and long-term (2012–2016) mean Atlantic basin track errors (red), in n mi.

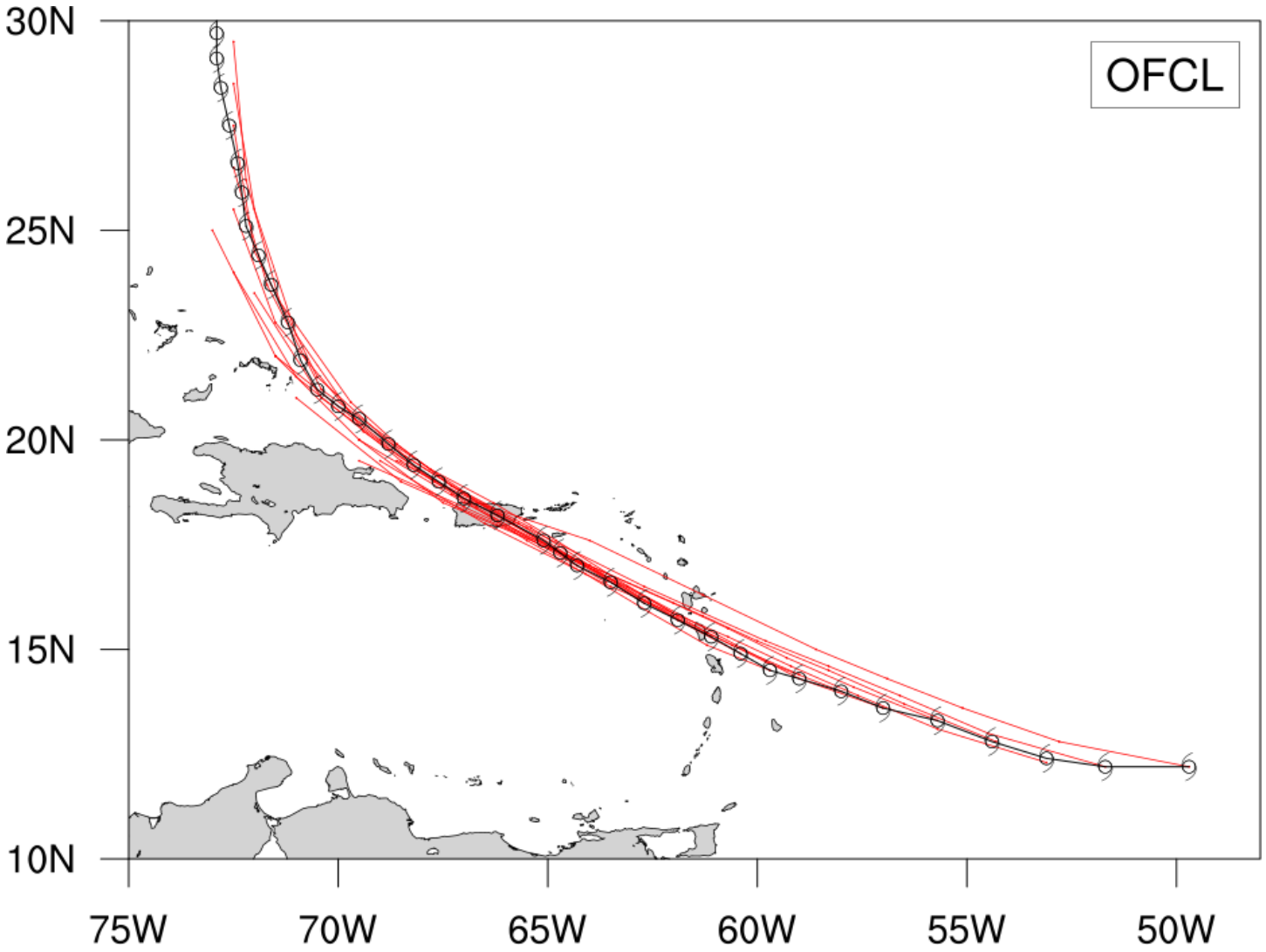

Figure 14. All official track forecasts for Maria from the time of genesis (1200 UTC 16 September) up to shortly before landfall in Puerto Rico (0000 UTC 20 September).

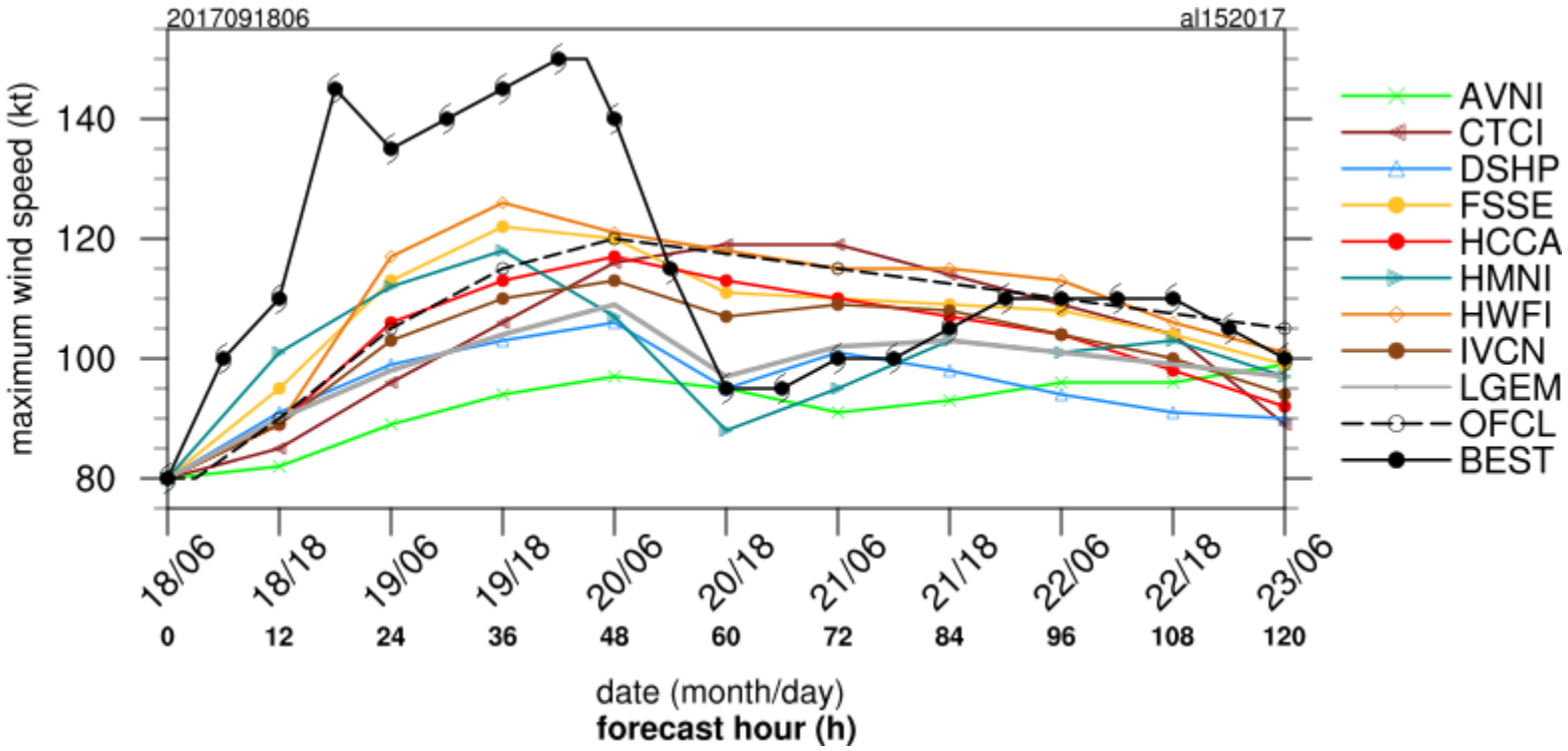

Figure 15. Best track intensity (solid black) and official (dashed black) and model (solid colors) intensity forecasts of intensity for Hurricane Maria from 0600 UTC 18 September 2017.