FloridaClimateCenter
Office of the State Climatologist

Hurricane Matthew – A Major 2016 Hurricane That Brushed Florida But Had Major Impacts

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General Overview

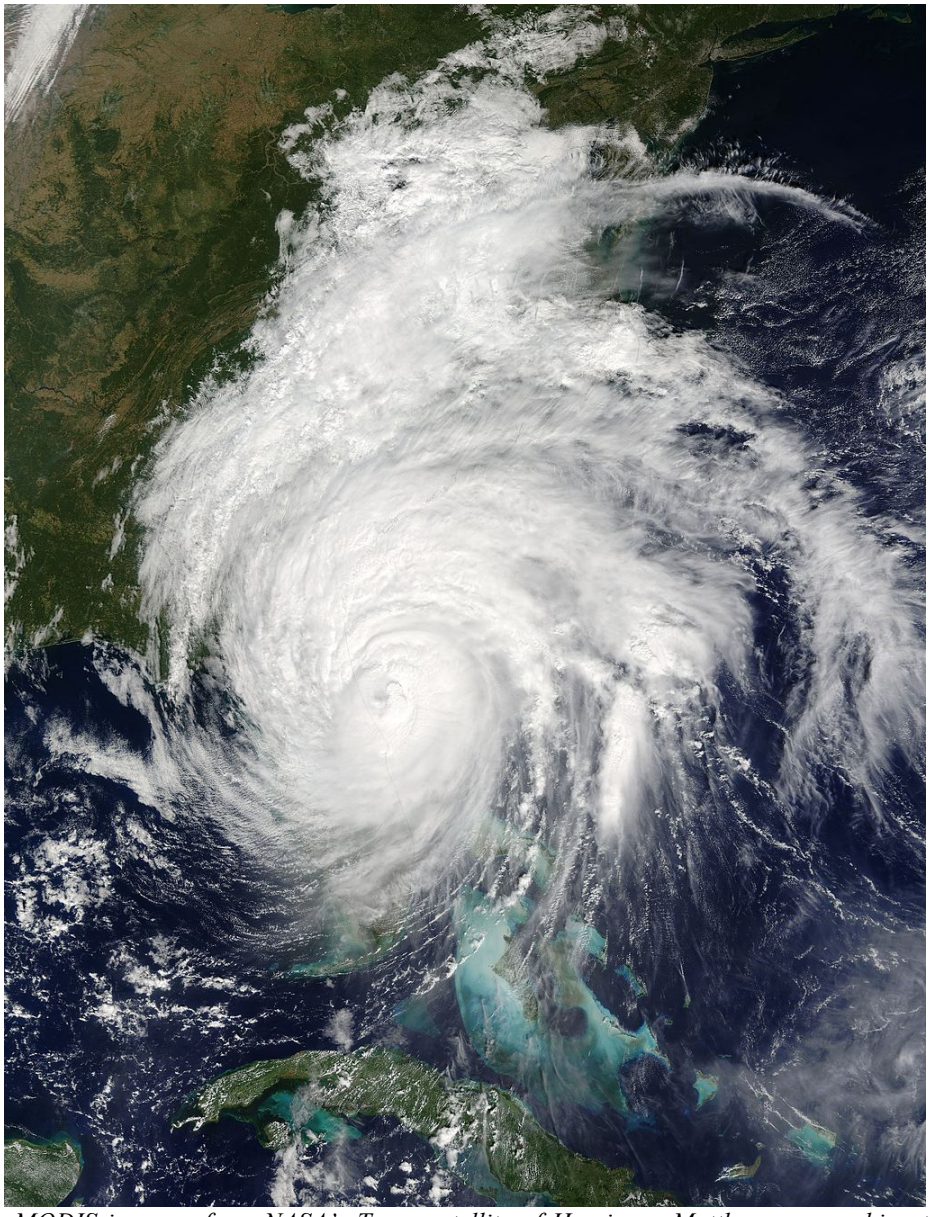

Figure 1: MODIS imagery from NASA's Terra satellite of Hurricane Matthew approaching the eastern coast of Florida on 7 October. Courtesy: NASA.

The center of Hurricane Matthew tracked just east of Florida's Atlantic coast on 7 October (Figure 2). It did so after quite a spectacular history. An easterly wave exited western Africa around 22 September, after which it moved just south of Cape Verde. By the time the wave had approached the Lesser Antilles, thunderstorm activity

developed. Passing by Barbados and having developed the requisite closed circulation, the tropical low was christened as Tropical Storm Matthew on the 28th. Thereafter, steered due westward by strong pressure and height ridging to the north, Matthew entered the Caribbean Sea and encountered very warm waters and a marginal wind shear environment. On the 29th, Matthew strengthened into a Category One hurricane. Despite the presence of northwesterly wind shear, the storm underwent explosive development and rose to Category Five strength by the afternoon of the 30th at a latitude of 13.3 degrees north of the Equator, making it the strongest hurricane on record at such a low latitude. Matthew also maintained Category Four or Five strength for the longest duration on record of any hurricane in the eastern Caribbean Sea. Slowing down and weakening slightly to Category Four strength, Matthew eventually turned northward on the 2nd and accelerated. On the morning of the 4th, it made landfall on Haiti at Category Four strength, making it the strongest hurricane to make landfall on the nation since Hurricane Cleo in 1964. That evening, it made landfall on eastern Cuba. Although the mountains of the Cuba disrupted the structure of the storm, Matthew was able to re-strengthen to Category Four strength between Cuba and the Bahamas. The storm then crossed the Bahamas -- making it the only storm on record to make landfall on all three of Haiti, Cuba, and the Bahamas as a major hurricane (Category Three or greater) -- and approached the eastern coast of Florida in the Melbourne area on the 7th. Thereafter, it paralleled the coast, with the center of the eye remaining 30 to 40 miles off shore, until it moved into waters off shore of Georgia late on the 7th. Ultimately, having maintained Category Three strength or greater for 7.25 days, Matthew was the longest-duration major (Category Three or greater) Atlantic tropical cyclone on record after 25 September.

Despite its notable impacts on Florida, discussed further in the next section, it is emphasized that Hurricane Matthew never, by definition, made landfall on Florida. The National Hurricane Center, which is the authority responsible for identifying hurricane landfalls and the locations of those landfalls, provides the following definition and explanation of landfall on its Web site:

> *[Landfall is] the intersection of the surface center of a tropical cyclone with a coastline. Because the strongest winds in a tropical cyclone are not located precisely at the center, it is possible for a cyclone's strongest winds to be experienced over land even if landfall does not occur. Similarly, it is possible for a tropical cyclone to make landfall and have its strongest winds remain over the water. Compare direct hit, indirect hit, and strike.*

As Matthew did not make landfall on Florida, the record streak of no major hurricanes making landfall on the state continues, stretching back to the landfall of Hurricane Wilma, rated Category Three, on 24 October 2005. Although Matthew did make landfall on South Carolina, it was not a major hurricane at that time. Therefore, the record streak of no major Atlantic-basin hurricanes making landfall on the United States also continues, stretching back to the landfall of Wilma in 2005.

Figure 2: Map showing track and intensity of Hurricane Matthew. Courtesy: Aaron Steckelberg, The Washington Post.

Impacts on Florida

Despite never making a landfall on the state, Hurricane Matthew had a considerable impact on the eastern coast of the Florida peninsula from the Treasure Coast northward. It brought historically high and damaging storm surge, tropical-storm- to hurricane-force winds, and heavy rains to the land mass.

Matthew may be most notable for its historically high storm surge, especially in Duval, Flagler, Nassau, and St. Johns Counties. Storm-surge heights for selected locations are shown in the following table.

LOCATION, BODY OF WATER	COUNTY	STORM SURGE HEIGHT (feet)
Fernandina Beach, Atlantic Ocean	Nassau	6.91[1]
Palm Coast, Saltwater Canal	Flagler	6
Mayport, St. Johns River	Duval	5.22[2]
Racy Point, St. Johns River	St. Johns	5.05
Dames Point Bridge, St. Johns River	Duval	4.19
Trident Pier, Atlantic Ocean	Brevard	4.09
Buckman Bridge, St. Johns River	Duval	2.43
Lake Worth, Atlantic Ocean	Palm Beach	1.68
Virginia Key, Atlantic Ocean	Miami-Dade	1.02

Notes:
[1]*Third-highest storm surge on record after 9.68 feet on 2 October 1898 (from a major hurricane that made landfall near Brunswick, Georgia) and 7.10 feet on 19 October 1944 (from the so-called Cuba-Florida hurricane of 1944).*
[2]*Second-highest storm surge on record after 8.50 feet on 2 October 1898.*

The storm surge flooded near-coastal roadways and structures, especially in such communities along the First Coast and St. Johns River as Flagler Beach, Jacksonville Beach, Palm Coast, St. Augustine, and St. Augustine Beach (Figure 3). The surge, along with high waves, severely eroded beaches and dunes and, in some cases, compromised structures and roadways (Figure 4).

Figure 3: Storm-surge flooding in St. Augustine Beach on the afternoon of 7 October. Courtesy: News4JAX.

Figure 4: Damage to the A1A in Flagler Beach from beach erosion caused by storm surge and high waves. Courtesy: Miami Herald.

Hurricane-force wind gusts were registered along and near the Space Coast, and tropical-storm-force sustained winds and gusts were registered at stations throughout the eastern half of the peninsula from near Miami northward. The following table displays storm-maximum sustained winds and wind gusts at selected stations.

LOCATION[1]	COUNTY	MAXIMUM SUSTAINED WIND (miles per hour)	MAXIMUM WIND GUST (miles per hour)
Cape Canaveral – USAF Tower No. 3[2]	Brevard	77	107
Vero Beach International Airport	Indian River	55	74
Daytona Beach International Airport[3]	Volusia	52	71
Melbourne International Airport	Brevard	53	70
Jacksonville Craig Municipal Airport	Duval	N/A	69
Jacksonville Naval Air Station	Duval	N/A	68
St. Lucie County International Airport	St. Lucie	45	68
Sanford Airport	Seminole	47	63
De Land Municipal Airport	Volusia	41	62
Stuart – Witham Field	Martin	41	61
Orlando International Airport	Orange	46	61
Fernandina Beach Municipal Airport	Nassau	N/A	60

Mayport Naval Station	Duval	N/A	60
Orlando Executive Airport	Orange	41	58
West Palm Beach International Airport[4]	Palm Beach	34	51
Gainesville Regional Airport	Alachua	N/A	48
Leesburg International Airport	Lake	31	48
Pompano Beach Air Park	Broward	38	47
Fort Lauderdale International Airport	Broward	24	45
Fort Lauderdale Executive Airport	Broward	30	44
Kissimmee Gateway Airport	Osceola	36	44
Hollywood Airport	Broward	26	41
Lake City Municipal Airport	Columbia	N/A	41
Opa-Locka Airport	Miami-Dade	28	40
Ocala Municipal Airport	Marion	N/A	39
Okeechobee County Airport	Okeechobee	31	39

Notes:
[1]All locations are associated with observation stations using either the Automated Surface Observation System (ASOS) or Automated Weather Observation System (AWOS) unless otherwise noted. Anemometer height is 10 meters and wind averaging is over two-minute intervals at ASOS/AWOS stations.
[2]U.S. Air Force (USAF) wind tower anemometers are mounted at a height of 54 feet, and their wind-averaging period is five minutes.
[3]This station stopped transmitting and recording data after 11:37 AM EDT on the 7th, likely because of power failure.
[4]Data from the duration of the storm are incomplete, likely because of power failure.

These strong winds caused structural damage that ranged from sporadic and minor in near-coastal southeastern Florida (e.g., a few trees and branches blown down, awnings ripped off buildings) to widespread and more substantial along the Space and First Coasts (e.g., many trees and branches down, building roofs de-shingled, many power lines and poles blown down). At the peak of the storm on the 7th, 1.1 million electric customers had lost electric power statewide. In the city of Jacksonville, widespread power failure caused many sewage lift stations maintained by the Jacksonville Electric Authority (JEA) to be non-operational, leaving the operational ones with an increased demand, which was only increased by run-off from heavy rainfall from the storm. As a result, the JEA was forced to dump 7.4 million gallons of raw sewage into the St. Johns River.

Rainfall totals due to Matthew were moderate to high in proximity to the coast from parts of the Treasure Coast northward and exhibited a sharp gradient westward across the peninsula that is typical of the more western half of tropical cyclones in the Atlantic basin (Figure 5). The greatest totals were in portions of Duval, St. Johns, Volusia, Putnam, and Flagler Counties.

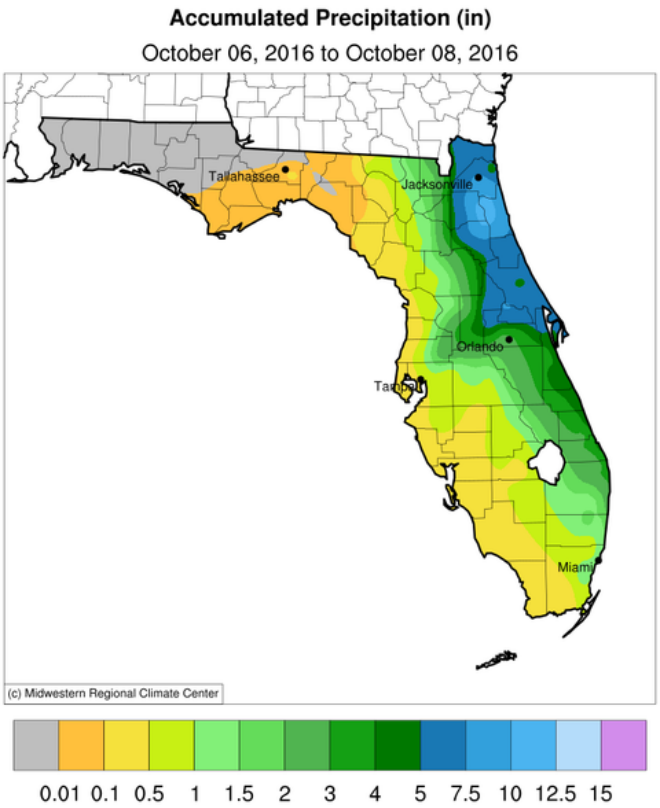

Figure 5: Plot showing Hurricane Matthew storm-total rainfall in Florida. Produced using the cli-MATE utility on the Web site of the Midwestern Regional Climate Center.

The following table displays storm-total rainfall amounts for select specific stations that recorded 3.00 inches or greater.

GAUGE LOCATION	COUNTY	RAINFALL TOTAL (inches)	OBSERVATION NETWORK
St. Augustine 12.2 WNW	St. Johns	9.97	CoCoRaHS
Jacksonville 12.0 SSE	Duval	9.63	CoCoRaHS
Jacksonville 3.8 ESE	Duval	9.55	CoCoRaHS
Fleming Island 2.2 S	Clay	9.29	CoCoRaHS
Sanford	Seminole	8.99	NWS COOP
Jacksonville 10.3 SW	Duval	8.15	CoCoRaHS
Orange Park 3.0 WNW	Clay	8.03	CoCoRaHS
Fleming Island 1.7 SE	Clay	7.91	CoCoRaHS
Jacksonville 11.4 ESE	Duval	7.89	CoCoRaHS
Lakeside 2.9 S	Clay	7.79	CoCoRaHS
Oak Hill 2.8 WSW	Volusia	7.75	CoCoRaHS
Jacksonville 4.8 SW	Duval	7.55	CoCoRaHS
Orange Park 4.1 WSW	Clay	7.54	CoCoRaHS
St. Augustine South 2.1 SSW	St. Johns	7.48	CoCoRaHS
Jacksonville 7.8 SW	Duval	7.44	CoCoRaHS

East Palatka 3.5 NNW	Putnam	7.20	CoCoRaHS
Sanford 1.9 WNW	Seminole	7.07	CoCoRaHS
Orange Park 0.7 NNE	Clay	7.05	CoCoRaHS
Jacksonville 5.9 SW	Duval	6.97	CoCoRaHS
Jacksonville 6.7 WSW	Duval	6.87	CoCoRaHS
Jacksonville 10.0 WSW	Duval	6.83	CoCoRaHS
Jacksonville 4.2 NE	Duval	6.82	CoCoRaHS
Lake Mary 5 WNW	Seminole	6.81	USGS
Jacksonville Craig Municipal Airport	Duval	6.75	ASOS
Hastings 4 NE	St. Johns	6.72	NWS COOP
Jacksonville 9.6 SE	Duval	6.70	CoCoRaHS
Jacksonville International Airport	Duval	6.63	ASOS
De Land 5.7 NW	Volusia	6.61	CoCoRaHS
Interlachen 10.4 NNE	Putnam	6.60	CoCoRaHS
Geneva 5 ESE	Seminole	6.33	USGS
De Leon Springs 6.4 ENE	Volusia	6.32	CoCoRaHS
Federal Point	Putnam	6.01	NWS COOP
Palm Coast 5.9 S	Flagler	6.00	CoCoRaHS
Palm Bay 2.6 SSE	Brevard	5.74	CoCoRaHS
Jacksonville 12.0 SSE	Duval	5.66	CoCoRaHS
Daytona Beach Shores 1.8 SSE	Volusia	5.65	CoCoRaHS
Jacksonville Naval Air Station	Duval	5.62	AWOS
Ormond Beach 3.5 SE	Volusia	5.53	CoCoRaHS
Orlando 7.4 WNW	Orange	5.52	CoCoRaHS
Keystone Heights 7.6 ENE	Clay	5.43	CoCoRaHS
Oviedo 4.0 W	Seminole	5.43	CoCoRaHS
Orange Park 4.8 SSW	Clay	5.28	CoCoRaHS
Titusville 3.5 NW	Brevard	5.26	CoCoRaHS
DeLand 2.0 W	Volusia	5.26	CoCoRaHS
Mount Plymouth 0.2 WSW	Lake	5.22	CoCoRaHS
Oviedo 1.6 SE	Seminole	5.22	CoCoRaHS
De Land 1.4 WSW	Volusia	5.20	CoCoRaHS
Keystone Heights 6.9 ENE	Clay	5.12	CoCoRaHS
Astor Park 5 SW	Lake	5.02	USGS
Orlando 7.2 WNW	Orange	5.01	CoCoRaHS
Keystone Heights 9.1 NE	Clay	4.98	CoCoRaHS
Palm Shores 4.3 NNW	Brevard	4.89	CoCoRaHS
Chuluota 0.9 N	Seminole	4.86	CoCoRaHS
Titusville 8 ENE	Brevard	4.76	USGS
Satsuma 4.0 NE	Putnam	4.72	CoCoRaHS
Pierson 2 WSW	Volusia	4.65	USGS

Keystone Heights 3.5 ENE	Clay	4.61	CoCoRaHS
Orlando 4.9 N	Orange	4.44	CoCoRaHS
Palm Bay 2.7 SSE	Brevard	4.38	CoCoRaHS
Middleburg 3.8 NW	Clay	4.34	CoCoRaHS
Keystone Heights 10.0 NE	Clay	4.30	CoCoRaHS
Orlando 4.8 NNW	Orange	4.19	CoCoRaHS
Sebastian 1.7 SSE	Indian River	4.18	CoCoRaHS
Orange 11.2 NE	Lake	4.15	CoCoRaHS
St. Augustine Airport	St. Johns	4.13	AWOS
Merritt Island 20 N	Brevard	4.10	USGS
Clermont 0.4 SW	Lake	4.07	CoCoRaHS
Vero Beach 3.4 W	Indian River	4.02	CoCoRaHS
Port St. Lucie 4.4 NNW	St. Lucie	3.98	CoCoRaHS
Winter Garden 6.1 SW	Orange	3.96	CoCoRaHS
Union Park 2.9 SSE	Orange	3.90	CoCoRaHS
Fort Pierce 8.6 NW	St. Lucie	3.82	CoCoRaHS
Astatula 1.0 E	Lake	3.80	CoCoRaHS
Melbourne – NWS Office	Brevard	3.80	NWS COOP
Stuart 3.7 SW	Martin	3.75	CoCoRaHS
Palm Shores 1.4 W	Brevard	3.74	CoCoRaHS
Ponce Inlet 0.5 S	Volusia	3.68	CoCoRaHS
Cocoa 2.6 WNW	Brevard	3.62	CoCoRaHS
Merritt Island 3.8 N	Brevard	3.62	CoCoRaHS
St. Lucie County International Airport	St. Lucie	3.62	ASOS
Interlachen 1.3 SW	Putnam	3.60	CoCoRaHS
Melbourne International Airport	Brevard	3.59	ASOS
Vero Beach 3.5 SSW	Indian River	3.58	CoCoRaHS
Groveland 1.7 E	Lake	3.58	CoCoRaHS
Daytona Beach International Airport	Volusia	3.58	ASOS
Savannas Preserve	St. Lucie	3.58	S. Fla. Water Mgmt. Dist.
Orlando 2.9 NNE	Orange	3.54	CoCoRaHS
Fort Pierce	St. Lucie	3.50	NWS COOP
Vero Beach International Airport	Indian River	3.42	ASOS
Bithlo 10 SSW	Orange	3.33	USGS
Port St. Lucie 2.4 N	St. Lucie	3.31	CoCoRaHS
Port Orange 2.9 WSW	Volusia	3.26	CoCoRaHS
Port St. Lucie 4.0 NE	St. Lucie	3.20	CoCoRaHS
Union Park 3.8 ESE	Orange	3.06	CoCoRaHS

Inland flooding of creeks and low-lying, poorly drained land and roadways was reported in Volusia, northern Brevard, Flagler, St. Johns, Putnam, and Duval Counties. Farmers in Putnam and St. Johns Counties reported substantial losses to their crops, averaging 30 to 60 percent, and a few farmers reported total losses. Recently planted crops of Asian vegetables and snap beans were especially damaged, with losses due to that damage estimated by the University of Florida Agricultural Extension at $1.6 million. Crops of cabbage, cauliflower, broccoli, winter squash, mustard greens, sweet corn, and sweet potatoes were also affected. Farmers blamed flooding and soggy soils from excessive rainfall due to both the hurricane and a stalled surface front just before the time of the hurricane.

No tornadoes occurred in Florida because of Hurricane Matthew.

Conclusion

Hurricane Matthew was the first hurricane to have such a high impact on Florida since the historically active 2005 season. It also appears to have been the strongest hurricane, or nearly so, to affect the First Coast region since at least September 1964, when Hurricane Dora made landfall near St. Augustine. Anticipating a more direct hit from the storm, emergency-management officials collectively called for the largest evacuation in Florida history. Nonetheless, even though Matthew did not make as direct a hit on the state as anticipated, nine Floridians perished as a direct result of the storm, and early estimates put damages in the hundreds of millions of dollars in Florida alone.

Supplemental Links

Each Florida National Weather Service Weather Forecast Office (WFO) whose County Warning Area was impacted by Hurricane Matthew published a post-storm summary…
Jacksonville:
http://nws.weather.gov/blog/nwsjacksonville/2016/10/09/quick-review-of-major-hurricane-matthew/
Melbourne:
http://forecast.weather.gov/product.php?site=NWS&issuedby=MLB&product=PSH&format=CI&version=1&glossary=0
Miami:
http://forecast.weather.gov/product.php?site=NWS&issuedby=MFL&product=PSH&format=CI&version=1&glossary=1

The Capital Weather Gang, the Washington Post's weather department, provided excellent near-real-time coverage of the storm while it affected Florida but also the Caribbean Sea before that and the rest of the Southeast after that. The stories published by its reporters can be found here:
https://www.washingtonpost.com/news/capital-weather-gang/

Brian McNoldy of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami has archived radar imagery of Matthew on his Web site:
http://andrew.rsmas.miami.edu/bmcnoldy/tropics/matthew16/Matthew_6-8Oct16_southeast.gif

The following link leads to an article from Fresh Plaza that discusses agricultural losses due to Matthew in St. Johns County as well as in the Caribbean and in the balance of the Southeast:
http://www.freshplaza.com/article/165207/May-take-a-decade-for-ag-to-recover-from-Hurricane-Matthew - .WAeR-NpYde4.twitter

The following link leads to the 17 October 2016 Florida Crop Condition and Progress Report published by the National Agricultural Statistics Service:
https://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Crop_Progress_&_Condition/2016/wc101716.pdf