Center for Disaster Management and Risk Reduction Technology

CEDIM Forensic Disaster Analysis Group (FDA)

Hurricane Irma

Information as of 09 October 2017 – Report No. 2

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SUMMARY

Official Disaster Name	Date	Landfall UTC	Local	Duration
Hurricane 10L Irma	**10-09**	**13:10 UTC Florida**	**-4**	
Tropical Disturbance, Depression, Tropical Storm, Hurricane Cat 1 - Cat 5	**27-08 – 14-09**			**19 days**

Preferred Hazard Information:

Location	Movement	Definition (Saffir-Simpson Scale)	Min Sea Level Pressure	Wind Gusts	Time	Wind Sustained
100 km W of Guinea-Bissau	**W**	**Tropical Disturbance**			**27-08 21 UTC**	**25 kt 46 kph**
450 km W of Guinea-BissauE	**NNW**	**Tropical Depression**	**1008 hPa**		**28-08 15 UTC**	**25 kt 46 kph**
750 km W of Cabo Verde Islands Verde	**W**	**Tropical Storm**	**1004 hPa**		**30-08 12 UTC**	**45 kt 83 kph**
850 km W of Cabo Verde Islands	**NW**	**Category 1**	**988 hPa**	**90 kt 148 kph**	**31-08 09 UTC**	**72 kt 133 kph**
900 km W of Cabo Verde Islands	**NW**	**Category 2**	**979 hPa**	**100 kt 185 kph**	**31-08 12 UTC**	**85 kt 157 kph**
950 km W of Cabo Verde Islands	**NW**	**Category 3**	**967 hPa**	**120 kt 222 kph**	**31-08 18 UTC**	**100 kt 185 kph**
830 km E of Antigua of Barbuda	**W**	**Category 4**	**944 hPa**	**140 kt 259 kph**	**04-09 18 UTC**	**115 kt 213 kph**
480 km E of Antigua and Barbuda	**WNW**	**Category 5**	**929 hPa**	**170 kt 314 kph**	**05-09 12 UTC**	**145 kt 269 kph**

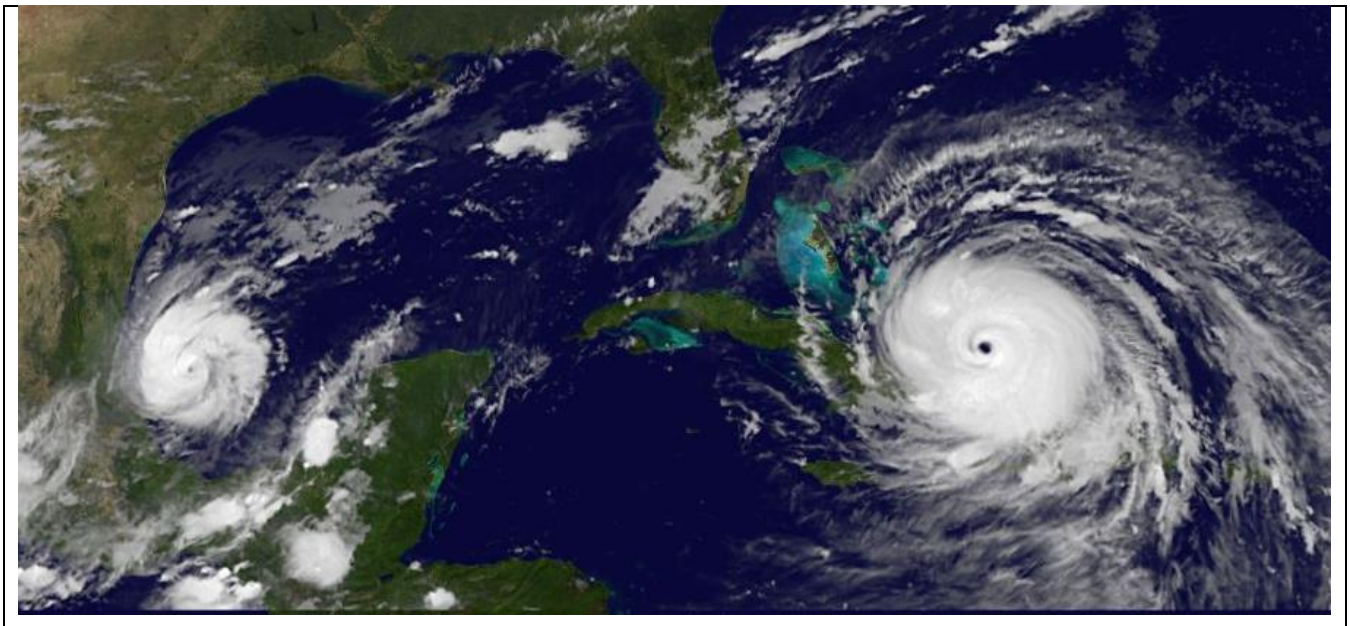

Figure 1: Satellite image showing Irma while entering the Bahamas and approaching Cuba on 08 Sep 2017, 07:00 UTC, and Katia just east of Mexico. Image credit: NASA GSFC GOES Project

1 Meteorological Information

1.1 Evolution of Hurricane Irma

Like most Atlantic September hurricanes Irma emerged from a Tropical Disturbance, that was immediately off the coast of Guinea-Bissau on 27 August 2017. Showers and thunderstorms that were associated with the disturbance began to organize over the next two days over the east Atlantic Ocean. They developed an independent circulation and satellite data suggested sustained winds of 45 kt (83 kph) on 30 September 2017. The system was classified as a Tropical Storm and was named Irma. At 1500 UTC, the center of the Tropical Storm Irma was located near 16.4 N and 30.3 W. That's about 675 km west of the Cape Verde Islands. Irma was moving toward the west near 11 kt (20 kph). Hurricanes Ivan (2004), Isabel (2003), Hugo (1989) and Allen (1980) are examples of past powerful hurricanes that formed near the Cape Verde Islands.

On the following day Irma intensified rapidly and within 12 hours Irma passed all steps from a Tropical Storm to a major category 3-hurricane. Average wind speeds increased from 60 kt (111 kph) to 100 kt (185 kph), the central pressure decreased by 30 hPa from 997 hPa to 967 hPa.

Hurricane Irma was moving west-northwestward with winds of about 100 kt (185 kph) when the GPM core Observatory satellite saw it on 01 September 2017 at 05:47 UTC. An powerful convective storm in a band of rain on Irma's northern side was dropping rain at a rate of almost 6.3 inches (159 mm) per hour. The center of Hurricane Irma was located near 18.5 N and 27.8 W about 2540 km east of the Leeward Islands.

With nearly unchanged intensity of category two or three Irma shifted westward over the Atlantic Ocean on 02 September 2017. Also on the following day sustained winds were in the range of 95 to 100 kt (176 to 185 kph).

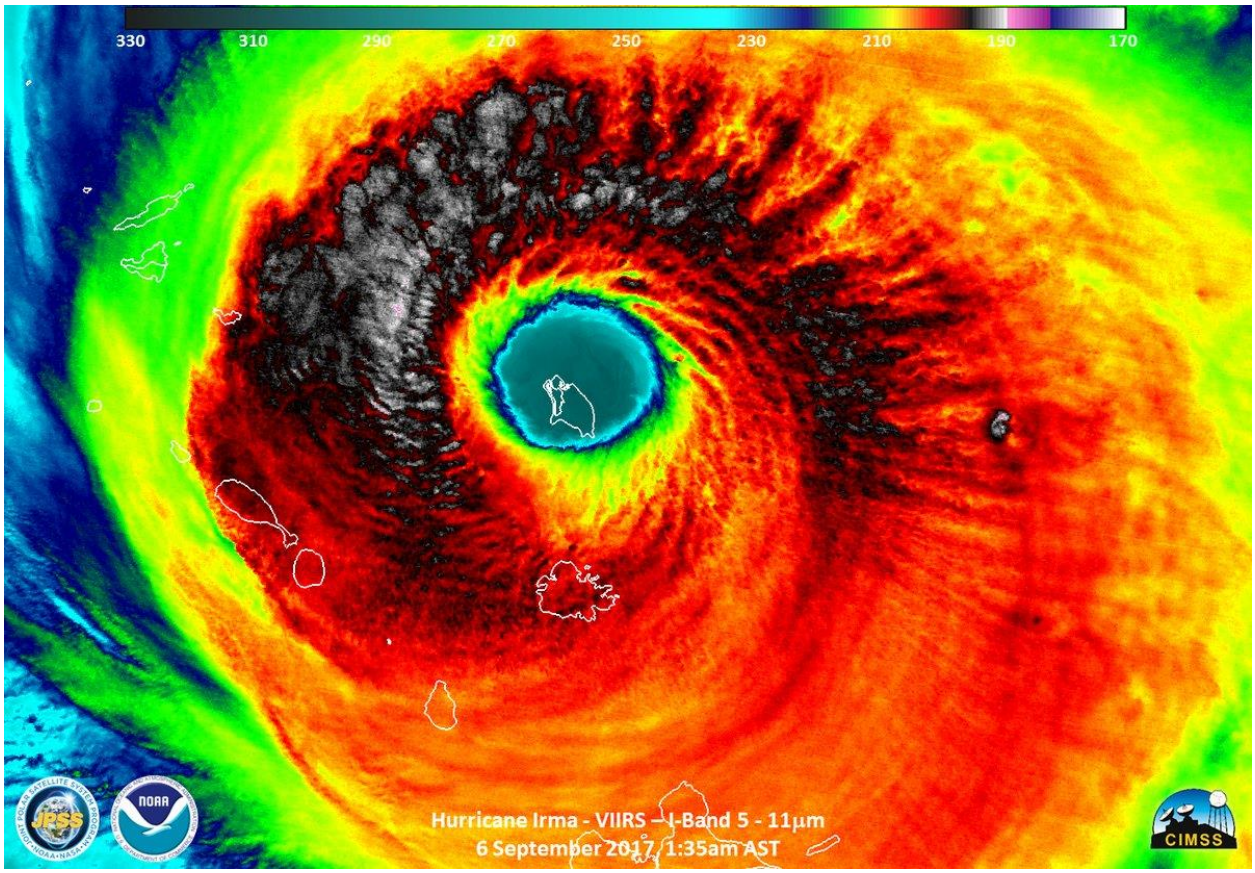

Figure 2: Satellite image showing Irma's directly over Barbuda, the eye's diameter is roughly 55 km. Data source: CIMSS

Large scale pressure patterns forced Irma from a westerly or northwesterly track to a south westerly direction. Still being a category 3-hurricane Irma entered the latitude of the Lesser Antilles.

On 04 September 2017 Irma made its way over an area with increased sea surface temperatures (29°C) and thus higher heat content fueled Irma's further development. Sustained wind speeds increased to 115 kn (213 kph) making Irma a hurricane of the second highest category 4. At this time Irma appeared fairly symmetric as a very well organized tropical cyclone with a well pronounced eye and spiralling rain band features. The upper tropospheric outflow was well developed all around the center, too, and the environmental atmospheric conditions were still very favorable for further intensification. On 04 September 2017 Irma was a major hurricane of medium size and hurricane blasts went as far as 200 kilometers from the center. Powerful thunderstorm clouds on Irma's western side reached heights of about 16 kilometers and had very cold cloud top temperatures of -83.5°C.

On 05 September 2017, the favorable conditions for intensification of tropical cyclones (sea surface temperatures of more than 29°C, low vertical wind shear of 5-10 kt and increasing ambient humidity) led to a rapid decrease in the central pressure which dropped from 943 hPa to 916 hPa within just 24 hours. Correspondingly, sustained eye wall winds increased from 120 kt (222 kph) to 160 kt (296 kph) making Irma an extremely dangerous category 5-hurricane and one of the strongest Atlantic hurricanes ever. NASA and NOAA satellites provided valuable satellite imagery to forecasters at the National Hurricane Center, and revealed that hurricane Irma has strengthened to a category 5-hurricane on 05 September 2017 around 12:00 UTC.

On the satellite images the huge eye of Irma is clearly visible. Radar measurements from NASA's Tropical Rainfall Measuring Mission (TRMM) showed a radar reflectivity of 80 dBz in the strongest thunderstorms.

Irma kept its intensity during 06 September 2017 and crossed several islands of the Lesser Antilles as a category 5 hurricane with sustained winds of 160 kt (296 kph). At 21 UTC Irma's lifetime minimum central pressure was 914 hPa. In comparison to other hurricanes on the Atlantic with similar intensity (for example Wilma, 2005: 882 hPa), the central pressure of "Irma" was significantly higher. The decisive factor for the high wind speeds is, however, the pressure gradient to the environment which was more pronounced in "Irma" due to geopotential anomalies in the surrounding area than during other Atlantic hurricanes.

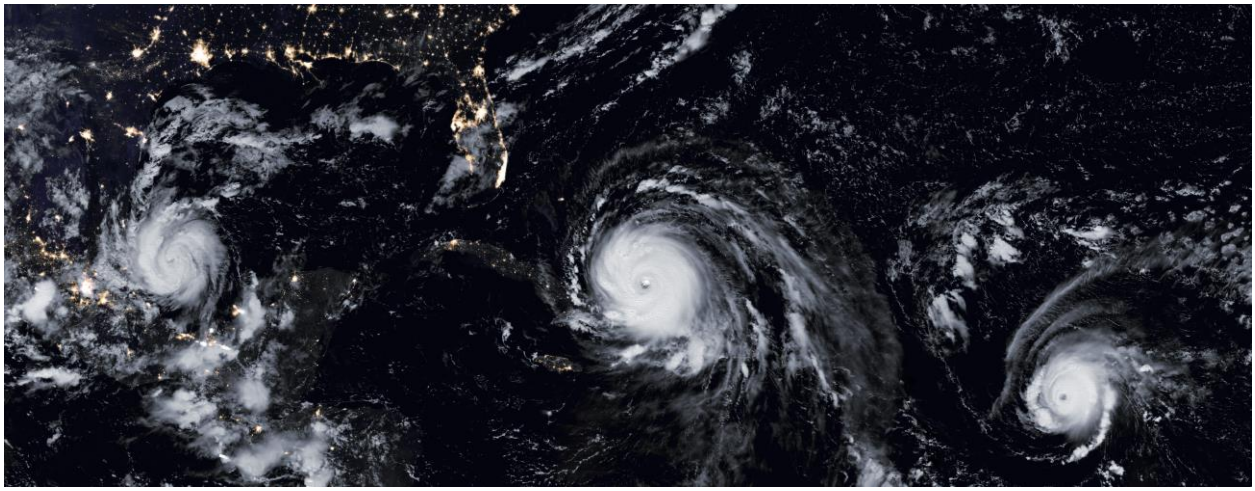

Figure 3: Satellite image showing 3 hurricane at the same time: Katia, Irma and Jose. Data source: NASA

The hurricane passed Puerto Rico with the southern eye-wall touching the island and Hispaniola. On 07 September 2017 a slight increase in central pressure was observed, however, in the evening with 269 kph Irma still was a very dangerous hurricane.

Irma's weakening probably was due to interaction of the storm's south side with the island of Hispaniola. Increased friction and dry air intrusion from the island's interior affected the circulation of the hurricane. Irma's western edge appeared not as symmetric as on the previous days. With reconnaissance flights hurricane hunters detected an eye-wall replacement cycle.

While moving northwestward Irmas slight weakening continued on 08 September 2017. Around 06 UTC Irma was an upper category 4-hurricane with average wind speeds of 135 kt (250 kph). Irma's rain bands covered large parts of eastern Cuba and were responsible for torrential rain falls. After the eye-wall replacement the eye was twice as large as the old one and had a diameter of 72 km. With the new eye and further increased sea surface temperatures Irma strengthened again and once more became a category 5-hurricane for some hours.

As Irma further moved along the coast of Cuba towards Cubas northern tip Irma weakened to a category 3-hurricane on 09 September 2017. Travelling away from the northern coast of Cuba and heading for the Florida Keys, Irma passed over very warm waters with temperatures of more than 30°C. These high sea surface temperatures enabled Irma to re-strenghten again into a category 4-hurricane.

On 10 September 2017 Irma made its two last landfalls, first in the Florida Keys as a category 4- and then near Naples as a category 3-hurricane.

Following a northern track over western Florida Irma lost hurricane status on 11 September 2017 around 12 UTC. At 15 UTC the center of Tropical Storm Irma was located near 30.3 N and 83.1 W. That's about 115 km east of Tallahassee, Florida.

Unitl 12 September 2017 the center of Irma moved to southwestern Georgia and then into east Alabama. At 09:00 UTC the center of Post-Tropical Cyclone Irma was located near 33.0 N and 85.2 W, 110 km southwest of Atlanta, Georgia.

On 13 September 2017 satellite images showed the remnants of Irma over the Midwest. The clouds stretched from Missouri to the southern tip of Lake Michigan. The following day remnant cloud were present and moving over upstate New York towards the Atlantic coast.

Table 1: The multiple landfalls of Irma

Landfall 1	06-09-17, 06 UTC	Northern coast of Barbuda	160 kt / 296 kph
Landfall 2	06-09-17, 11 UTC	Sint Maarten	160 kt / 296 kph
Landfall 3	06-09-17, 17 UTC	Ginder Island and Tortola, British Virgin Islands	160 kt / 296 kph
Landfall 4	08-09-17, 06 UTC	Little Inagua Island, Bahamas	140 kt / 259 kph
Landfall 5	09-09-17, 03 UTC	Multiple Landfalls in the Sabana-Camagüey-Archipelago, Cuba	140 kt / 259 kph
Landfall 6	10-09-17, 13:10 UTC	Cudjoe Key, Florida, USA	115 kt / 213 kph
Landfall 7	10-09-17, 19:35 UTC	Marco Island, Florida	100 kt / 185 kph

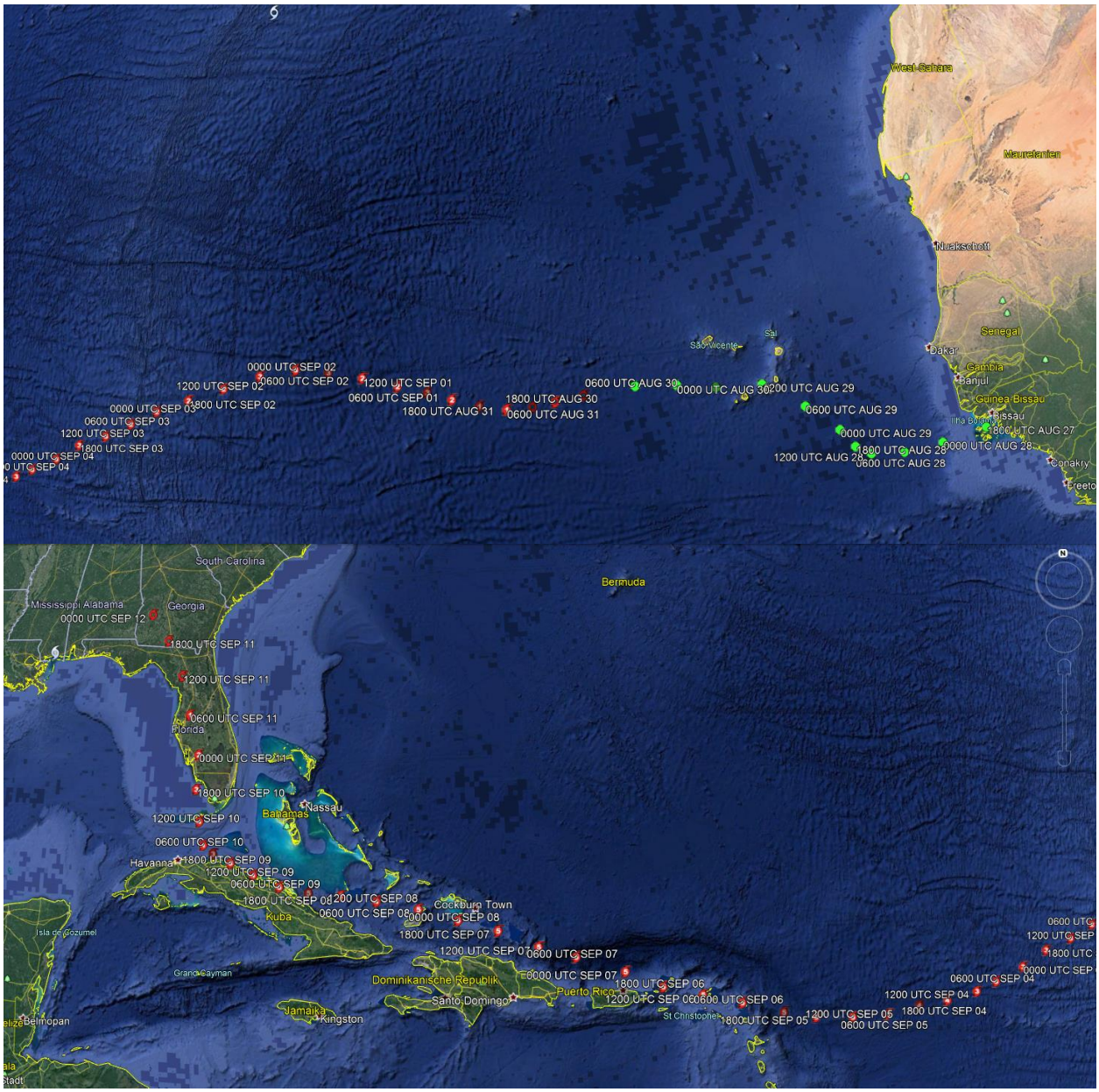

Figure 4: Track and intensity of Irma (27 August – 12 September 2017). Above: Eastern part of track from Guinea Bissau to central tropical Atlantic. Below: western part of track until dissipation over the U.S. Data source: National Hurricane Center

1.2 Precipitation

Along its track Irma brought rainfall totals of often more than 150 mm. Satellite data indicate the most rain over Cuba and the greatest amounts were observed in Guantanamo, Cubas easternmost province, where Irma dumped 406 mm of rain. Over the U.S. Irma unloaded the most rain east of the storm's center in an area between Fort Myers, Tampa, Orlando and West Palm Beach which received more than 200 mm; around 400 mm were reported from Fort Pierce on the eastern side of Florida. Also in far north eastern Florida rain amounts exceeded 200 mm and Edisto Island in South Carolina got 154 mm of rain, St Marys River in Georgia recorded 257 mm.

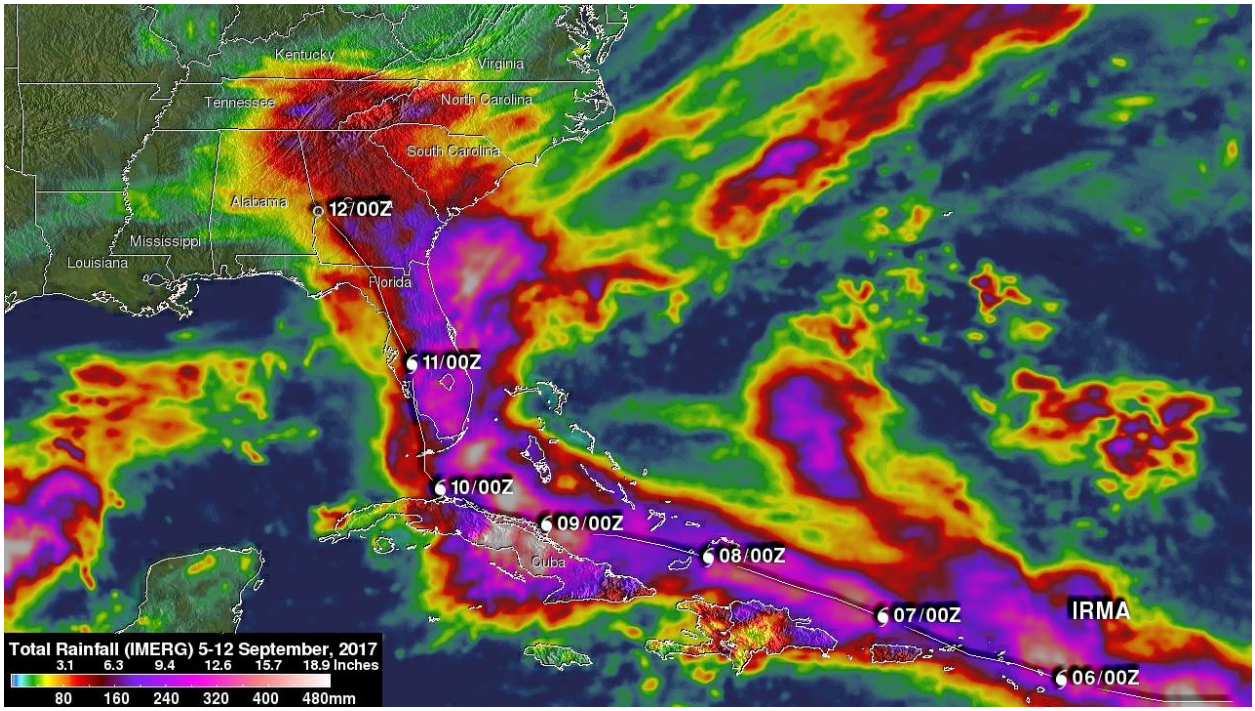

Figure 5: 7-Day rainfall totals along Irma's track (calculated from satellite data). Image credit: NASA

Table 2: Selection of storm total rain amounts (09 September 2017, 12 UTC – 12 September 2017, 02 UTC). Data source: NWS Weather Prediction Center

Fort Pierce St. Lucie Cnty Intl Arp	Florida	404 mm
Oviedo	Florida	375 mm
Chekika	Florida	351 mm
Inlikita	Florida	346 mm
Gainesville	Florida	310 mm
Mims	Florida	308 mm
Naples	Florida	301 mm
Eufaula Muni Arpt	Alabama	83 mm
St Marys River near Kingsland	Georgia	257 mm
Cumberland Sound near St Marys	Georgia	233 mm
Edisto Island	South Carolina	154 mm

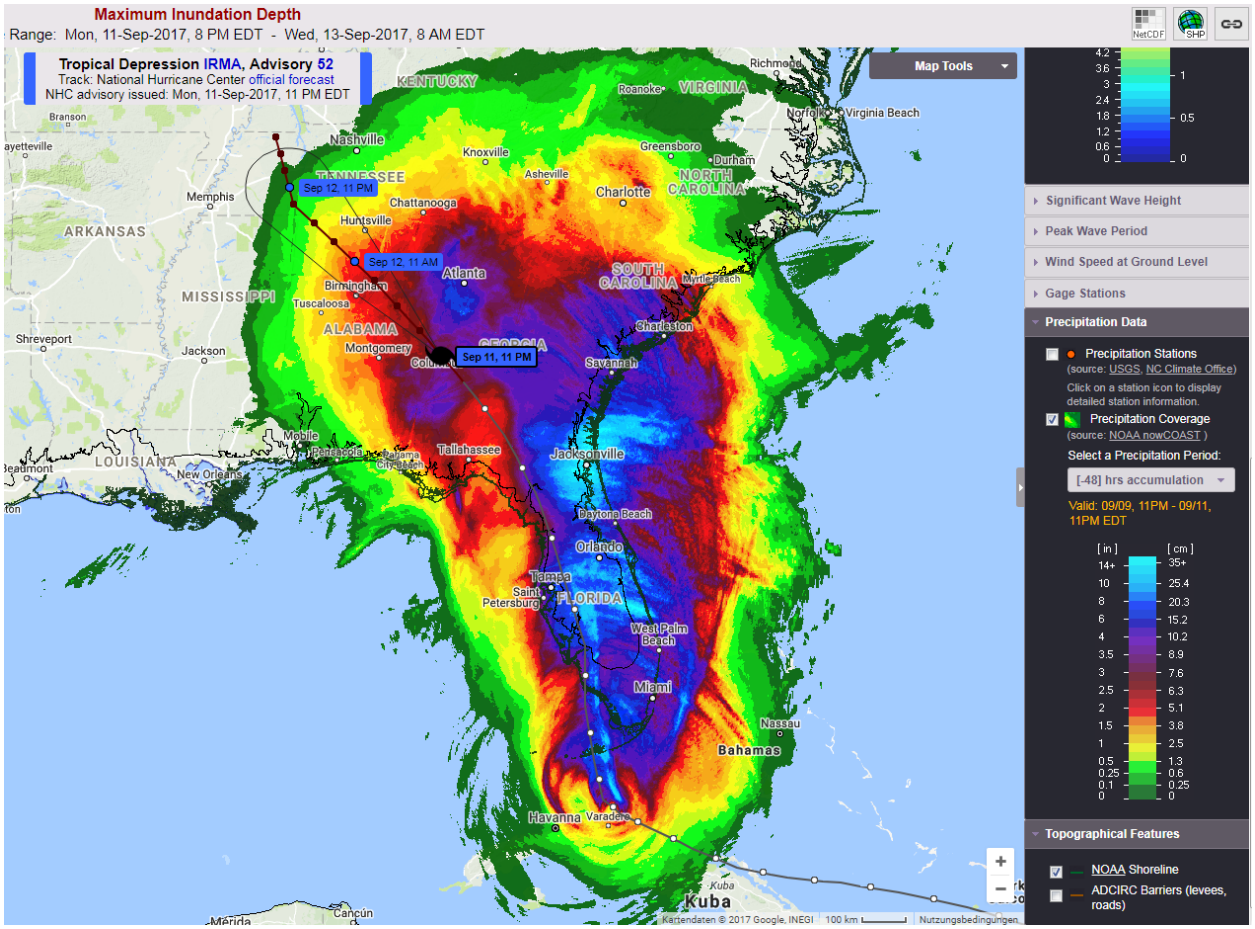

Figure 6: 48 hours-rainfall totals from 10 September 2017, 03 UTC, until 12 September 2017, 03 UTC. Image credit: http://nc-cera.renci.org/

1.3 Wind

With its last landfall on Marco Island in southwestern Florida (10 September 2017, 19:35 UTC) Irma came ashore as a category three hurricane. Closeby is the city of Naples which observed the highest wind gust of 228 kph, Marco Island reported 209 kph.

Table 3: Selected peak wind gusts in south eastern U.S. related to Irma

Naples	Florida	228 kph
Marco Island	Florida	209 kph
Lely	Florida	196 kph
Big Pine Key	Florida	193 kph
Quail Creek Estates	Florida	180 kph
North Perry Airport	Florida	175 kph
Fort Sreven	Georgia	113 kph
Parris Island	South Carolina	122 kph
Gatlinburg	Tennessee	97 kph

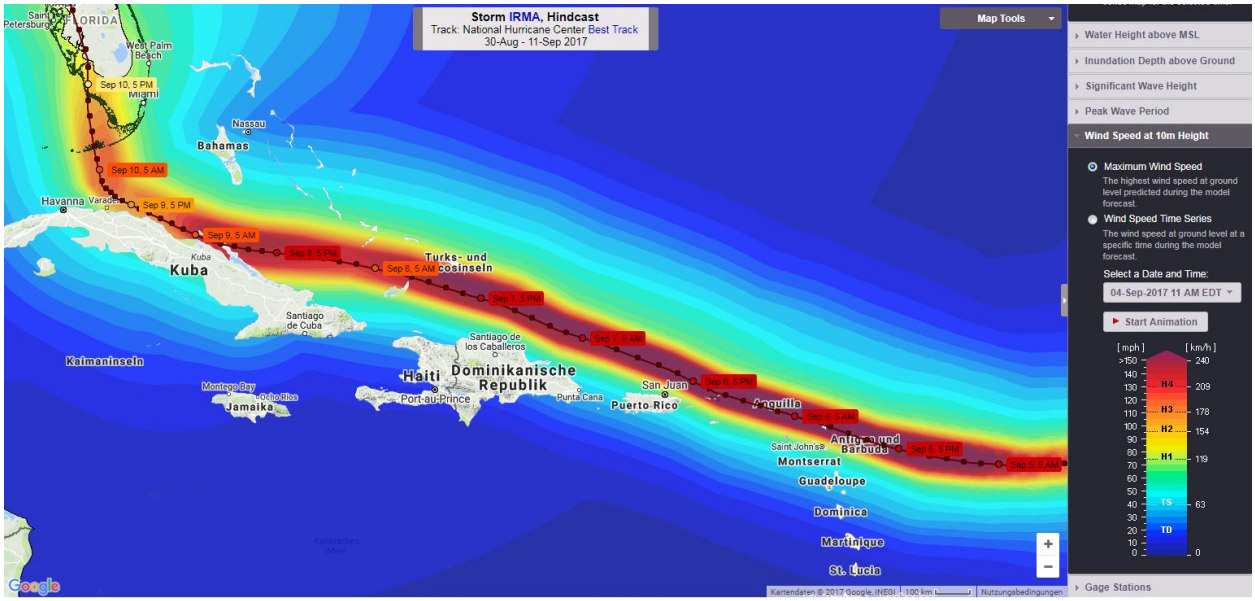

Figure 7: The highest wind speed at ground level predicted during the model forecast (5 -10 September 2017). Image credit: http://nc-cera.renci.org/

2 Facts that made Irma an extraordinary and record breaking hurricane

Landfalls:

- It was the first time in 166 years that two Atlantic category 4-hurricanes, Harvey and Irma, made landfall in the United States in the same year, they both came along with sustained winds of 210 kph. However, including the Pacific Ocean it happened before when in 1992 Andrew made landfall in Florida and Iniki hit Kauai, HI.
- Since 1851 only 27 category 4-hurricanes made landfall in the U.S., including Harvey and Irma; three of them were category 5-hurricanes.
- Before 2017 there was no category 4-hurricane hitting the U.S. since Charley came ashore in southwest Florida in 2004. Before that in 1992 Andrew devastated parts of southern Florida as a category 5-hurricane.
- Irma was the first category 4-hurricane to make landfall in Florida since Charley (2004) and first major hurricane since Wilma (2005).
- Irma came ashore in Florida with a central pressure of 929 hPa, making it the 7th lowest on record for U.S. landfall (together with Okeechobee Hurricane of 1928).
- Irma's intensity during landfall and the location was exact the same as in 2005, when Wilma came ashore as category 4-hurricane at 25.9°N 81.7°W.
- Irma was the first category 5-hurricane that made landfall in Cuba since the Cuba Hurricane of 1924.
- Irma made landfall in the Bahamas as category 5-hurricane, the previous such strong hurricane was Andrew in 1992.
- Irma made the closest approach to the Turks and Caicos archipelago of any category 5-hurricane on record.

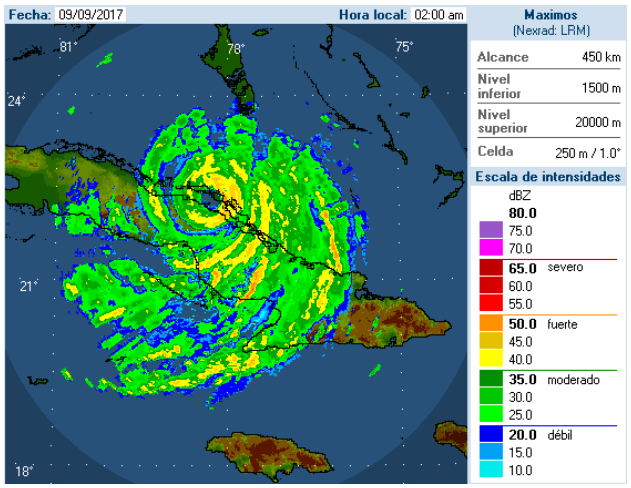

Figure 8: Radar image from 09-09-17, 06 UTC, while Irma is raging through Cubas Archipelago de Cmagüey. Image credit: http://www.met.inf.cu

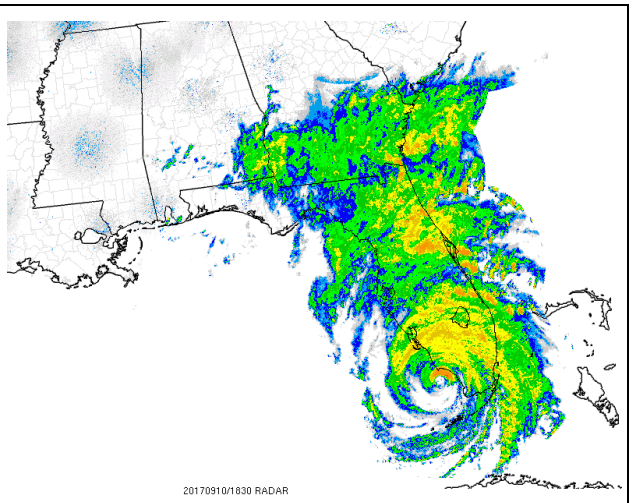

Figure 9: Radar image from 10-09-17, 18:30 UTC, one hour before Irma's final landfall in Florida. Image credit: http://www.weather.gov/Radar

Intensity:

- Irma kept category 5 for 3.25 days in total (not continuous), tying it with the Cuba Hurricane in 1932 for the longest lifetime as a category 5-hurricane. With respect only to the satellite era that began in 1966, Irma was the longest-lived category 5 hurricane.
- Irma was a category 5 hurricane for 3 consecutive days, the longest period of any hurricane in the Atlantic in the satellite area since 1966.
- Irma had hurricane strength (sustained winds at least 65 kt) for 11.25 days, the most since Ivan (2004) and the 9th most in the satellite era in the Atlantic. Since 1966 the record holder is Ginger (1971) with 19.5 hurricane days.
- Irma was a major hurricane (category 3 or above) for 8.5 days, which is the 2nd most since 1966 for the Atlantic following Ivan (2004).
- Only 3 other Atlantic hurricanes reached maximum sustained winds of 160 kt (298 kph): Allen (1980), Gilbert (1988) and Wilma (2005). Allen was the strongest with sustained winds of 306 kph.
- Irma was the strongest hurricane to exist in the Atlantic Ocean outside of the Caribbean and the Gulf of Mexico on record.
- Irma continued sustained winds of 160 kt (298 kph) for 37 hours. Never before any tropical cyclone kept that strength for such a long time anywhere in the world. The previous record holder was Haiyan (2013) that destroyed the city of Tacloban in the Philippines and kept winds of that intensity for 24 hours.
- Irma was the first category 5-hurricane in the Atlantic since Matthew (2016) and first in the tropical Atlantic (7.5-20°N, 60-20°W) since Hugo (1989)
- Irma was the most powerful hurricane ever raging through the Leeward Islands, defined as 15-19°N, 65-60°W for this calculation (and widely destroying Barbuda, Anguilla, Saint Martin). When battering some of the Leeward Island, Irma was at peak intensity with 160 kt sustained winds. Irma overtopped the Okeechobee Hurricane (1928) and David (1979) which both had 140 kt (257 kph) at their peak in the Leeward Islands.
- The minimum central pressure of Irma was 914 hPa on 06 September 2017, the lowest pressure since hurricane Dean in August 2007. Since 1966, when satellite hurricane observations began, Irma had the tenth-lowest central pressure. It was the lowest pressure by an Atlantic hurricane outside of the western Caribbean and Gulf of Mexico on record.

Table 4: Earth's strongest Tropical Cyclones at Landfall by sustained wind speed. Source: Wunderground

Super Typhoon Haiyan	Samar, Philippines	2013	165 kt / 306 kph
Super Typhoon Meranti	Itbayat, Philippines	2016	165 kt / 306 kph
Super Typhoon Joan	Taiwan	1959	160 kt / 296 kph
Great Labor Day Storm	Florida, USA	1935	160 kt / 296 kph
Hurricane Irma	Leeward Islands	2017	160 kt / 296 kph
Cyclone Winston	Fiji	2016	155 kt / 287 kph
Super Typhoon Megi	Luzon, Philippines	2010	155 kt / 287 kph
Super Typhoon Zeb	Luzon, Philippines	1998	155 kt / 287 kph

3 Consequences of Irma

3.1 Number of fatalities

Irma was a deadly hurricane and caused fatalities in many countries along its track. According to Wikipedia Irma was responsible for a total of at least 132 deaths (as of 30 September 2017).

Table 5: Number of fatalities due to Irma

USA	88	Barbuda	3
French West Indies	11	Puerto Rico	3
Cuba	10	Unknown locations	2
Sint Maarten	4	Anguilla	1
U.S. Virgin Islands	4	Barbados	1
British Virgin Islands	4	Haiti	1

The deadliest hurricane since 2000 was Katrina in 2005 with 1200 deaths.

3.2 Flooding due to storm surge

Irma had a great impact on coastal areas due to storm surge. Many locations and tidal gauges observed highest values on record. Especially affected were north eastern Florida, coastal Georgia and coastal South Carolina. With Irma moving northwards over western Florida, on the western side of the storm strong and persistent winds blew onshore from south easterly to north easterly directions. High tides in combination with storm surge pushed sea water towards the coast; the concave shaped coastline and the flat areas along the Atlantic coast between Jacksonville, Florida, and Savannah, Georgia, is particularly vulnerable to flooding. Moreover, runoff due to torrential rains exacerbated the flooding situation.

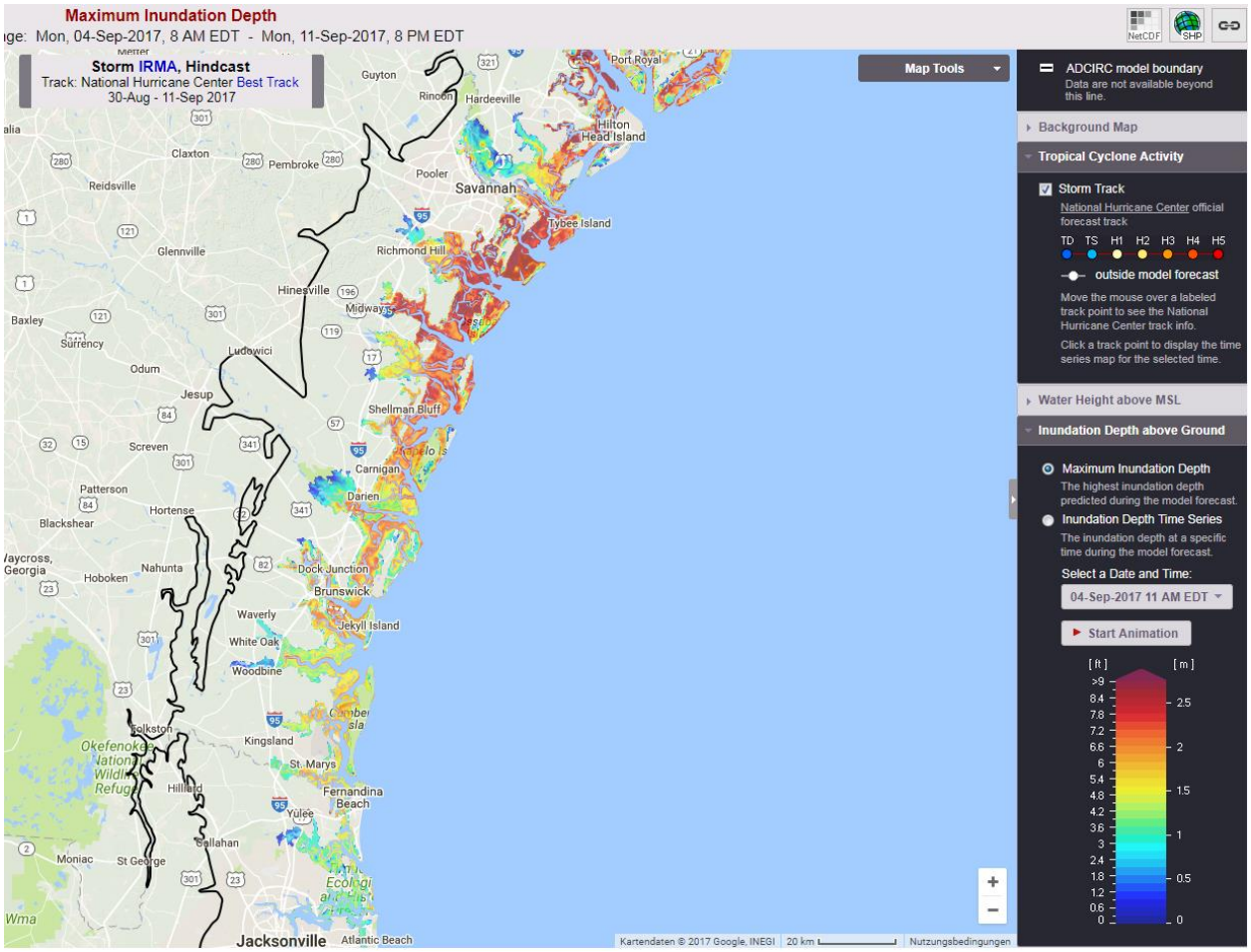

Figure 10: The maximum inundation depth above ground predicted during the model forecast. Image credit: http://nc-cera.renci.org/

St. Johns River in Jacksonville had water levels not seen since 1846. The gauge at downtown Jacksonville's Main Street Bridge saw a water level of 5.57 ft; the previous record was 4.12 ft on 10 September 1964 during hurricane Dora. Further to the north the tidal gauge at Fort Pulaski, Georgia, observed its second-highest value following the record set on 8 October 2017 with hurricane Matthew.

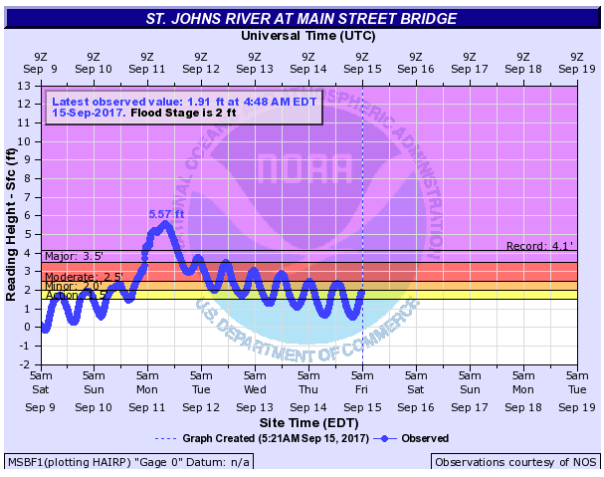

Figure 11: Time series of the river gauge at St. John's River in Jacksonville, Florida. Image credit: https://water.weather.gov

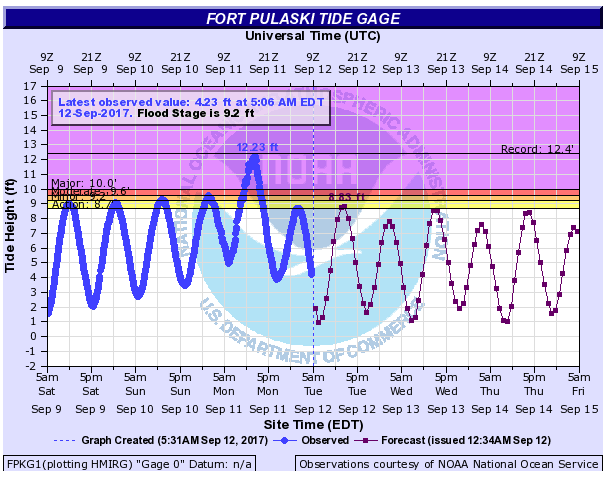

Figure 12: Time series of the tide gauge at Fort Pulaski, Georgia. Image credit: https://water.weather.gov

In Savannah the seawall was swamped and water flew into downtown streets. And in South Carolina the tidal gauge at Charleston Harbor observed 9.92 ft which is the third highest value behind the record set by hurricane Hugo on 22 September 1989 and the second highest flood event on 11 August 1940. Those previous two surges were due to direct hits of hurricanes while Irma passed with its center more than 300 kilometers away. Charleston's historic center witnessed its third major flooding in three years, flowing Matthew in 2016 and Joaquin in 2015.

3.3 Damages due to Irma

Hurricane Irma has racked up billions in damages. For amounts of loss see CEDIM's first report on Irma:

http://www.cedim.de/download/CEDIM%20FDA%20Irma%202017%20Situation%20Report%20No.%201.pdf

The first island of the Lesser Antilles which was hit by Irma was Barbuda. While crossing Barbuda Irma was at full strength with sustained winds of 296 kph. Before the wind measurement device failed, a gust of 249 kph was observed. The impact of Irma on the island and its buildings and infrastructure was calamitous. About 90% of the islands buildings and facilities were damaged leaving a barely habitable surrounding. Fallen trees and power poles disrupted electricity supply and telecoummunication. In addition to disastrous wind gusts, the storm surge of 2.5 meters above normal caused serious damage. Similar damage occurred in St. Barthelemy, St. Martin/St. Maarten, on British and American Virgin Islands, Turks and Caicos Islands, and the southern Bahamas as well as in parts of Cuba.

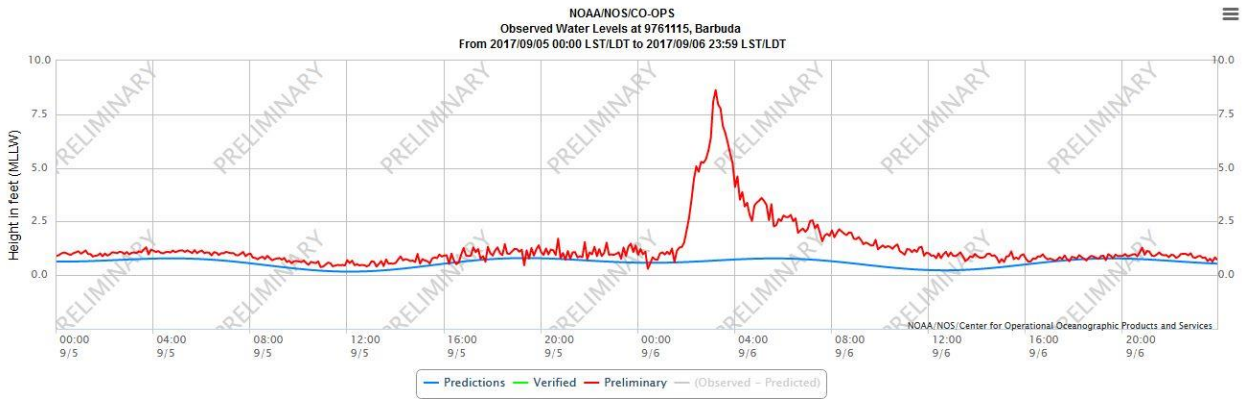

Figure 13: Time series of observed water level in Barbuda, 05-06 September 2017. Image credit: https://tidesandcurrents.noaa.gov/

Figure 14: Devastation on Sint Maarten. Image credit: Severe Weather Europe

Figure 15: Devastation on Sint Maarten. Image credit: Severe Weather Europe

Sources:

https://www.nasa.gov/feature/goddard/2017/irma-atlantic-ocean
https://twitter.com/philklotzbach?lang=de
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tropicalatlantic.com
NWS, Weather Prediction Center
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wunderground.com
water.weather.gov
CIMSS Tropical Cyclone Group
Tropical Rainfall Measuring Mission (TRMM)
NASA Earth Observatory
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https://tidesandcurrents.noaa.gov/
https://en.wikipedia.org/wiki/Hurricane_Irma

4 Effects of Irma on Florida

4.1 Irma's impact on Florida's power grid

Irma caused one of the largest natural disaster-related power outages in the U.S. history. On 11th September 6.5 million households were knocked out, nearly 15 million people were without power.

Compared to former hurricane related power issues:

- 1992 hurricane Andrew left 1.4 million people,
- 2005 hurricane Wilma 3.4 million customers,
- 2012 hurricane Sandy 8.2 million people without power.

On 8th September Florida's two nuclear plants – Florida Power & Light's turkey point, St. Lucie, both along Florida's Atlantic Coast - shut down in anticipation of hurricane-force winds.

Chronological order of power outages:

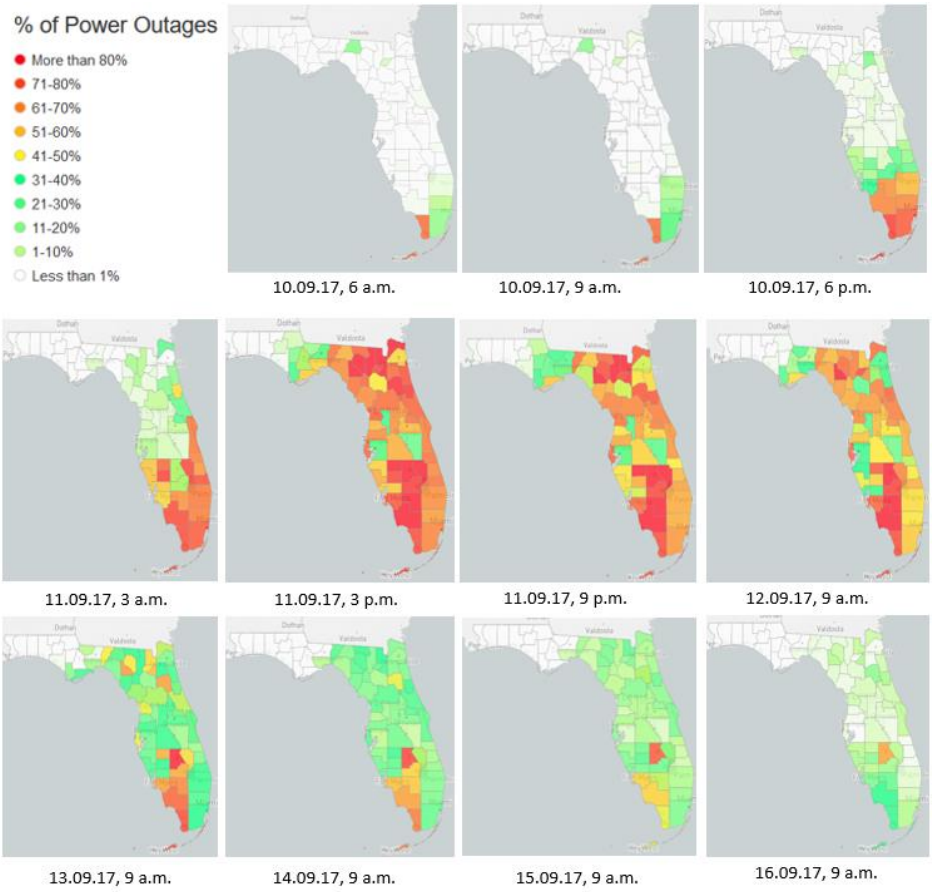

Figure 16: http://data.tallahassee.com/storm-power-outages/?tf=2017-09-10-120000

4.2 Damages on physical structures and human beings

Physical structures

Poles toppled due to high winds or fallen trees. Floods caused damages to electrical substations that link transmission lines with local distribution lines. Many buildings connected to the grid also have sustained damage to their electrical systems.

Remarks and facts:

Since 2006 Florida Power & Light (FPL) has invested more than $3 billion in measures like replacing wooden poles with sturdier concrete poles, burying some power lines and installing flood monitors at 223 substations to protect equipment. Burying power lines is very expensive: The city of Tallahassee estimated that it would cost $2 billion to bury its lines.

A 2012 study from the Edison Electric Institute estimates the costs for placing urban overhead powerlines underground at $174,000 for rural and $11 million per mile. Other estimations result in the following: $1.4 million per mile in the countryside and $30 million per mile in cities. For utilities it seems to be easier to focus on restoring power after storms than preventing outages during them. The electricity utility FPL serves about half of the state's 20 million residents along the southern coasts and has 90 percent of its customers within 20 miles of the coast. Placing cables underground might not always be the best strategy: putting power lines underground can increase the risk of flood damage, so the move would only trade one hazard for another.

Human beings

There are eight losses of live indirectly caused by hurricane Irma – all of them were elderly people living in a nursing home in Broward County. Since an air conditioning was cut off from power these people died between Tuesday and Wednesday due to heat stress.

Table 6: Temperature/humidity in the residency

Day	Temperature – max.	Humidity – max.
10.9.	32,0 °C	94 %
11.9.	36,7 °C	50 %
12.9.	42,8 °C	67 %

Failure of air conditioning contributes to a particular risk in Florida, where about 20% of the residents are 65 or older - people in that age range are more prone to heat-related health problems. Typically, there is a prioritized restoration process by a utility, respecting critical infrastructures like hospitals and communication networks before moving to major population centers. Non-highly populated areas are usually last in line. Robert Gould, chief communications officer of Florida's largest utility FPL, said that in a hurricane planning meeting earlier this year Broward County did not list this nursing home as a critical infrastructure. This nursing home explained the hurricane had knocked out a transformer that powered the air conditioning. Broward County reported that on Tuesday the home alerted officials that it had lost power, but when asked if it had any medical needs or emergencies, it did not request help. Close to the stifling nursing home was a fully air-conditioned hospital.

4.3 Mass evacuation in Florida

One of the biggest evacuations ever – an estimated 6.3 million people were ordered to evacuate, according to the Florida Division of Emergency Management (DEM). With regard to mass evacuation Florida's traffic infrastructure has the following special features. Florida relies on two primary highways that go north and south: IS 95 along the east coast and IS 75 further west.

Florida has established evacuation zones in coastal regions: A, B, C, D, and E.

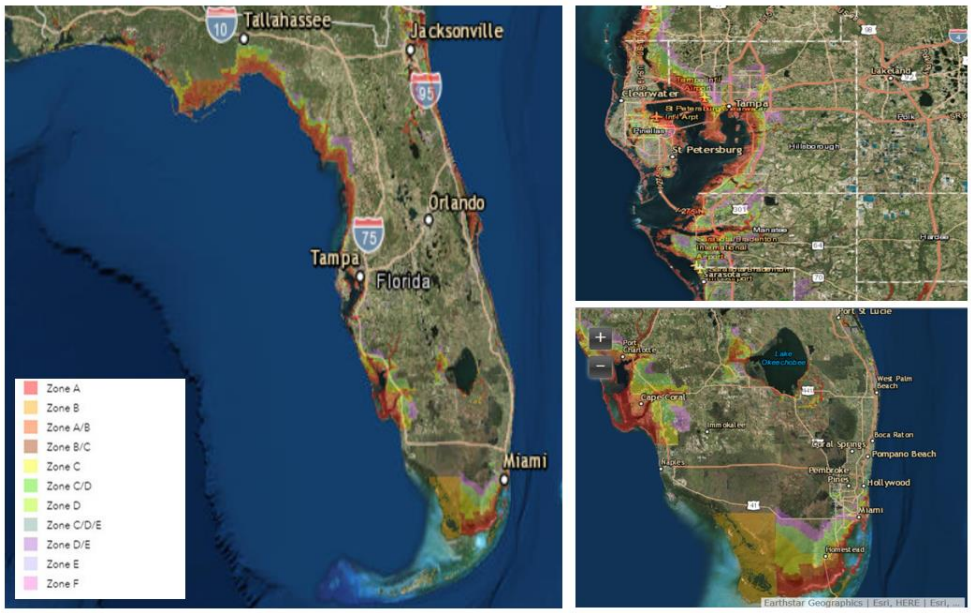

Figure 17: http://www.floridadisaster.org/publicmapping/

Chronology of evacuation related decisions, made or triggered by Florida's DEM:

	Thurs., 7.9.	Fri., 8.9.	Sat., 9.9.
Mandatory evacuation	South Bay, Lake Harbor, Pahokee, Moore Haven, Clewiston, Belle Glade, Canal Point Flagler: for nursing homes, all varieties of assisted living facilities, and community residential group homes within coastal and Intracoastal areas, Glades – Around Lake Okeechobee, Hendry: low - lying areas, non-slab-built homes, mobile home and RVs, areas near Lake Okeechobee Monroe: visitors and residents St. Lucie: for north and south Hutchinson Island, low-lying areas	Collier, Goodland, Everglades City, Chokoloskee, all mobile homes, Lee: Barrier Islands -Bonita Beach, Fort Myers Beach, Sanibel, Captiva, and Pine Island, Pinella: low-lying areas and all mobile homes Tampa Bay	
Zone A	Pinellas, all mobile homes	Broward, East of Federal Highway including barrier islands	Merritt Island, Barrier Islands, and some low-lying mainland areas along Indian River Lagoon
Zone A, B	Palm Beach		
Zone A, B, C	Miami-Dade –portions of C		
Zone A, B, C, F	Flagler		Flagler Martin: barrier islands, manufactured homes, and low-lying areas
Voluntary evacuation	Voluntary evacuation: Charlotte Hardee: for low-lying areas, mobile homes, and port structures		
Zone A	Manatee, Sarasota		

Measures taken by the Florida Department of Transportation (FDOT) – partially triggered by Florida's DEM:

Traffic management measures by FDOT tackling a main challenge: Balancing traffic flow issues and risks in emergency.

	Tue., 5.9.	Wed., 6.9.	Thurs., 7.9.	Fri., 8.9.	Sat., 9.9.
Activities by FDOT	Suspension of tolls for the duration of the storm's impact				
			Cooperation with the Florida Highway Patrol (FHP) to implement a limited Emergency Shoulder Use (ESU) plan for Hurricane Irma evacuations on I-75 at Wildwood to north of U.S. 90 in Columbia County. Motorists should only use the left shoulder when directed by law enforcement. The main goal: increase of traffic capacity during Hurricane Irma evacuations using existing paved shoulders.		
			Increase of the number of road rangers who are patrolling Florida's roadways 24/7 to assist motorists. 13 Traffic Management Centers where hundreds of workers are monitoring traffic cameras 24/7 to ensure traffic flows continue and evacuations proceed without interruption.		
			Monitoring road cameras at the State Emergency Operations Center in Tallahassee around the clock to help keep traffic moving.		
			Preparing with Google's emergency response team to *close* roads in Google Maps in real time in the event that Hurricane Irma forces the closure of any roads in the aftermath of the storm. Google Maps are used for Uber and Waze among other directional applications.		
			Suspending construction contractor work and preparing key evacuation routes for possible shoulder use.		
			Cooperation with county emergency operations centers directly to coordinate any necessary response actions, including activating traffic counters, providing local evacuation. Supporting and providing maintenance of traffic and other assistance.		

No Contra-flow: DEM Director Bryan Koon, said that using road shoulders allows emergency vehicles and crews to enter evacuated areas. Switching roads to one direction, known as contra-flow, is a **last resort**. “The contra-flow makes it harder for vehicles that need to go into those areas that are being evacuated and it takes up a lot of manpower that can be used elsewhere,” Koon said. “We’ll use it if we’ve tried everything else.”

Traffic development 7th – 9th September

7th September:

Floridians have begun to evacuate the state *in bulk*, resulting in a traffic jam that stretched approximately 780 miles from Miami to Chattanooga, Tennessee. This type of near-standstill conditions haven't been seen since Hurricane Floyd in 1999 - making a trip that would normally take 5-6 hours ran nearly double. The FDOT reported that the traffic load of many stretches of interstate were quadruple compared to the normal head count.

Figure 18: Google map traffic reports: red, orange indicating heavy congestion; evacuations cause gridlocks for example in Port St. Lucie

Fuel carrier vehicles were escorted by police to ensure delivery, though it couldn't come soon enough for some of those trapped in the gridlock. Contractors have come up with 1.5 million gallons to deliver so far. About 300,000 barrels of fuel were unloaded from a ship in Tampa to resupply gas stations. A fuel ship from Mississippi departed towards the Port of Tampa.

8th September:

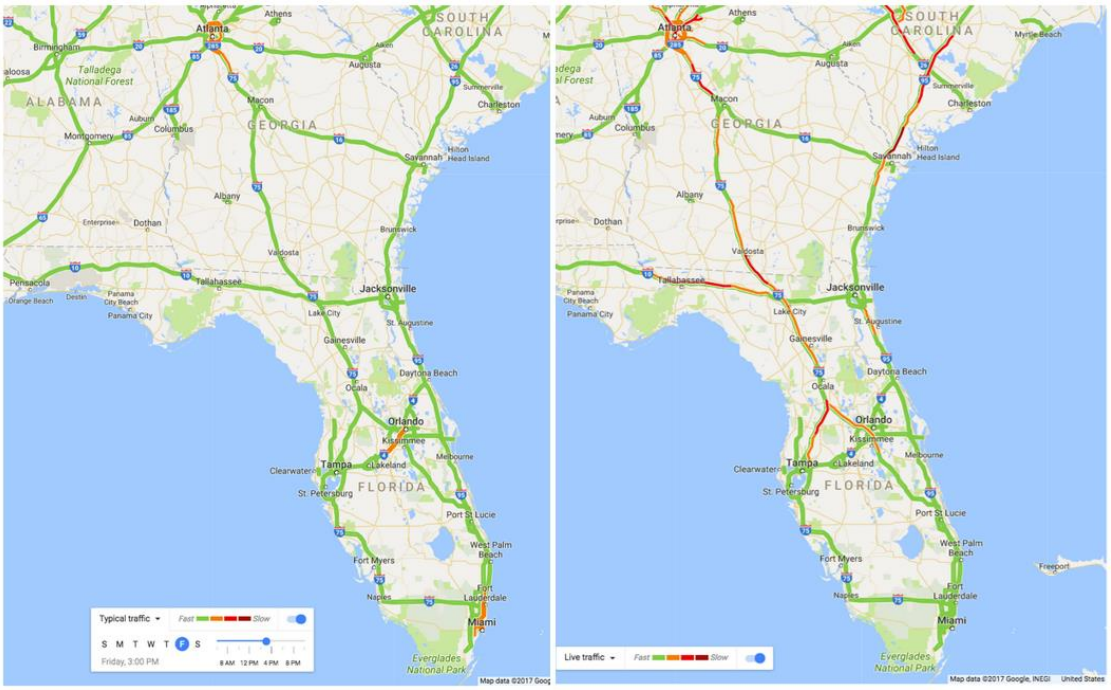

Figure 19: left: normal traffic state; right: traffic state on 8.9.

According to live traffic data from Google Maps, road-going evacuees had mostly cleared out of Southern Florida by late Friday afternoon, with heavy congestions emerging in the middle of the state instead. I-75, to the south of Ocala, got the worst of it, where the main road meets the Florida Turnpike, containing the vehicles coming out of Orlando. Traffic in the areas to the north clogged the roads all the way up through Tallahassee, Florida, and Atlanta. FDOT and the FHP have opened the shoulder from Wildwood near the Villages to the Georgia state line I-75. Motorists should only use the left shoulder when directed by law enforcement and highway signs, officials said. Right shoulder use was prohibited. No other state roadways were approved for shoulder use, and there were no highways designated as one-way only – **no contra-flow**!

9th September:

On the Interstate 4 only the left shoulder was open to motorists, indicated by FHP troopers, police and highway signs. According to FDOT officials, the right shoulder was not open. Even though there have been heavy loads of evacuees on some stretches of I-4, traffic was basically flowing on the highway.

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5 Further Reading

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