

What Happened?

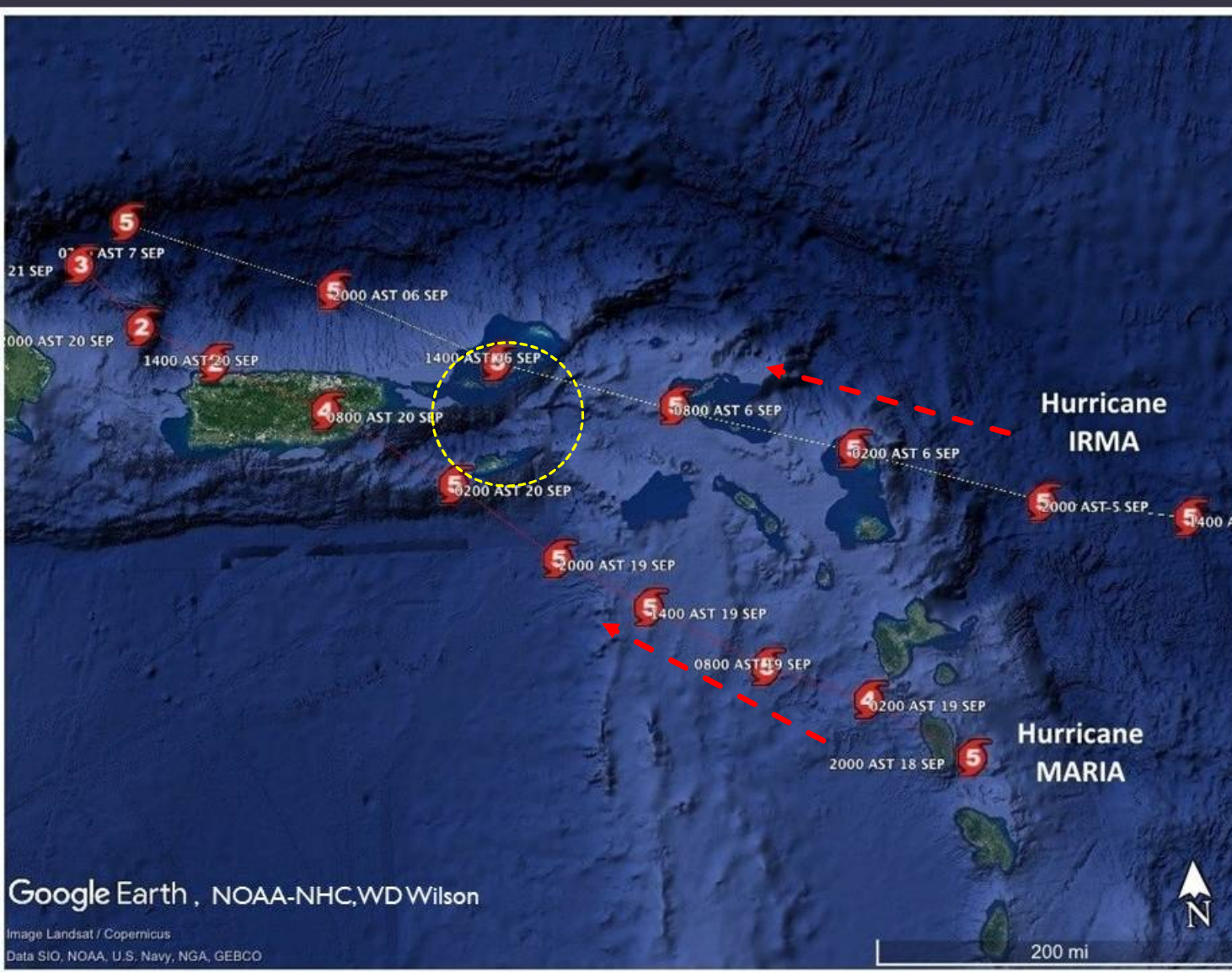
Irma and Maria
-- the back-to-back
Category 5 Hurricanes
of September 2017
in the US Virgin Islands

OCOVI Ocean and Coastal Observing - Virgin Islands
supporting **CARICOOS** 
in the Virgin Islands



OCEAN AND COASTAL OBSERVING – VIRGIN ISLANDS, INC. (OCOVI)

WWW.OCOVI.ORG



Two weeks apart, hurricanes Irma (September 6th) and Maria (September 20th) followed paths that sandwiched the Virgin Islands. Both remained Category 5 storms as they transited the VI region. Irma set a record of ~ 3¼ days in Category 5.

What makes our region particularly prone to tropical storms or hurricanes?

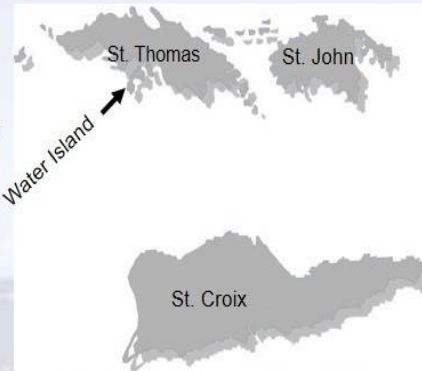


- ▶ Abundant warm ocean water, Temperature $\geq 80^{\circ}\text{F}$ (26.5°C) --the ocean water's heat provides the energy for convection which creates storms;
- ▶ Start-up moisture and spin from pre-existing systems (e.g., waves coming from the African continent);
- ▶ Favorable distance from the equator in order to maximize the spin (Latitude $> 4^{\circ}$ is necessary to maintain the necessary spin; the VI is located around 18°N);
- ▶ Remoteness from competing continental systems which can deplete atmospheric moisture;
- ▶ Remoteness from sources of wind shear;
- ▶ Minimal land surface (less debilitating friction, less deprivation of moisture).



Who are we?

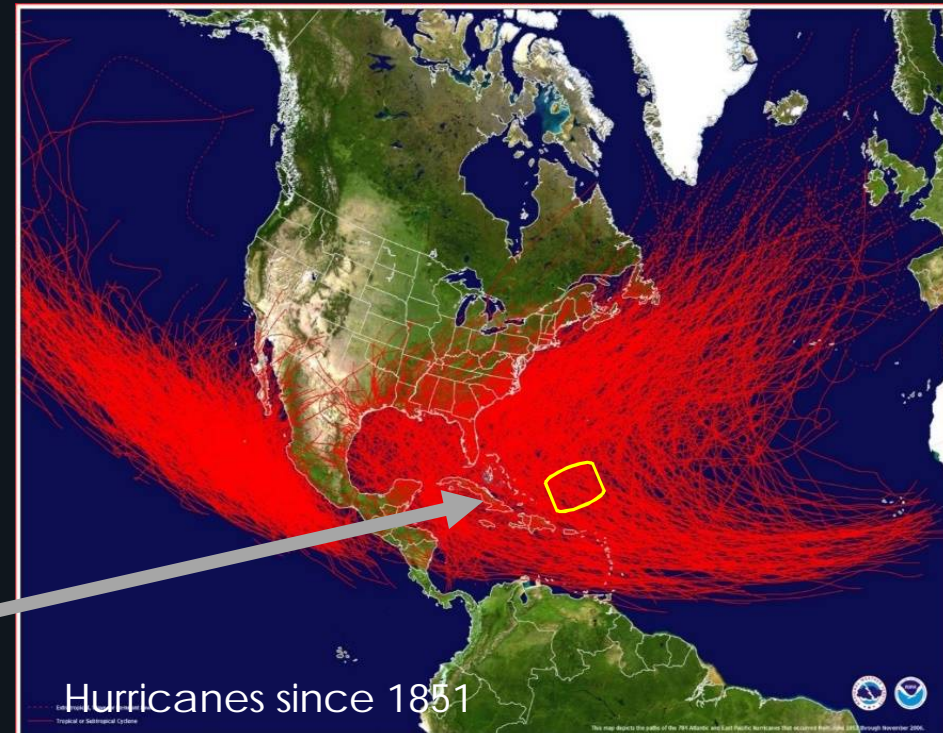
Profile of the
US Virgin Islands today
(*St. Croix, St. John,
St. Thomas, Water Island*):



- * Part of the United States since 1917
- * Population >106,000 (down from 2000)
- * Gross Domestic Product < \$4 Billion
- * ~2.48 million air & cruise ship arrivals annually
- * ~ \$500M spent by cruise ship passengers in a typical year
- * Seismic zone 4 in Uniform Building Code (1997)
- * Demonstrably located in “hurricane alley”.



Where are we?



Significant quote

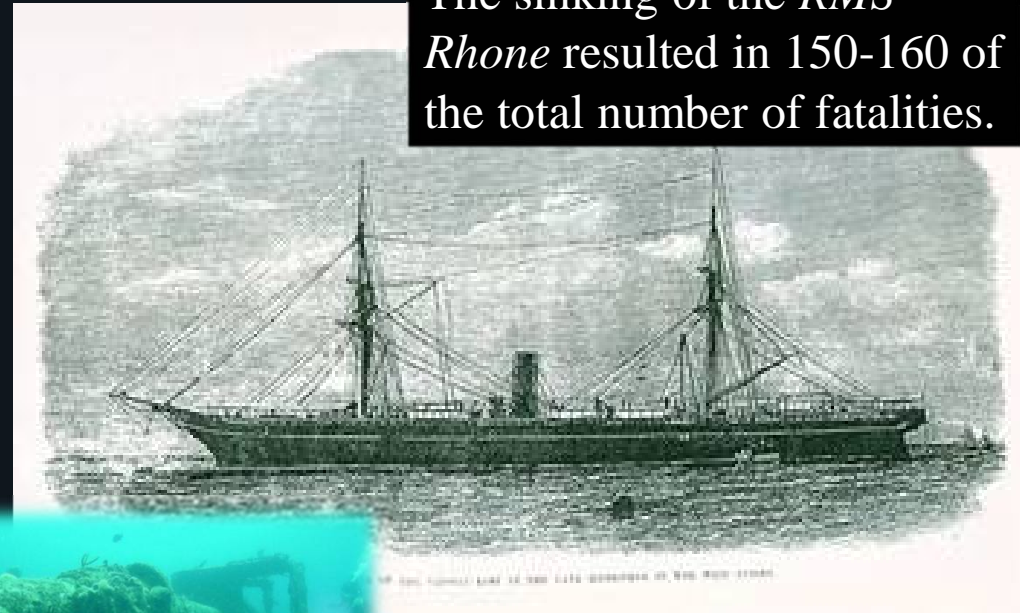
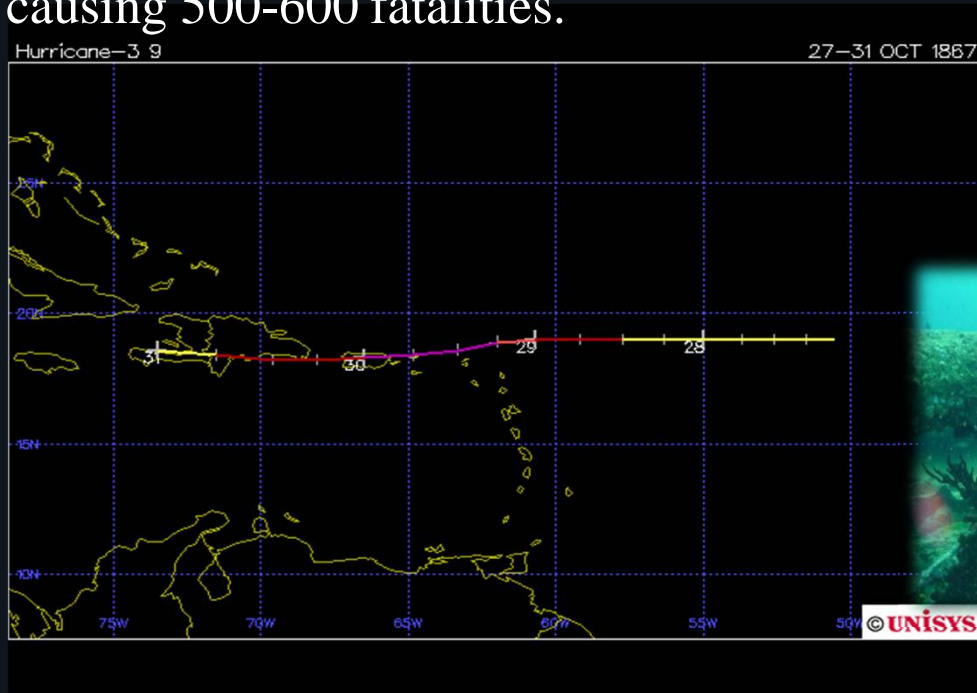
Alexander Hamilton describing the 1772 hurricane on St. Croix in the Royal Danish American Gazette, August 31, 1772:

... Good God! what horror and destruction—it's impossible for me to describe—or you to form any idea of it.... A great part of the buildings throughout the Island are levelled to the ground—almost all the rest very much shattered—several persons killed and numbers utterly ruined ...our harbour is entirely bare...".

From: "The Virgin Islands Our New Possessions and the British Virgin Islands" by Theodoor De Booy and John T. Faris, 1918.

In 1867 the *San Narciso* hurricane heralded the opening of a disastrous fall season* for the Danish West Indies

The hurricane on October 29th devastated the northern Virgin Islands and Puerto Rico causing 500-600 fatalities.



The sinking of the *RMS Rhone* resulted in 150-160 of the total number of fatalities.



* A major earthquake and accompanying tsunami would follow twenty days later.

Other more-recent hurricanes followed in the tradition of San Narciso (1867): David (1979), Hugo (1989), Marilyn (1995), Bertha (1996), Hortense (1996), Georges (1998), Lenny (1999)...



Photo: FEMA, 1995



Photo: FEMA, 1995

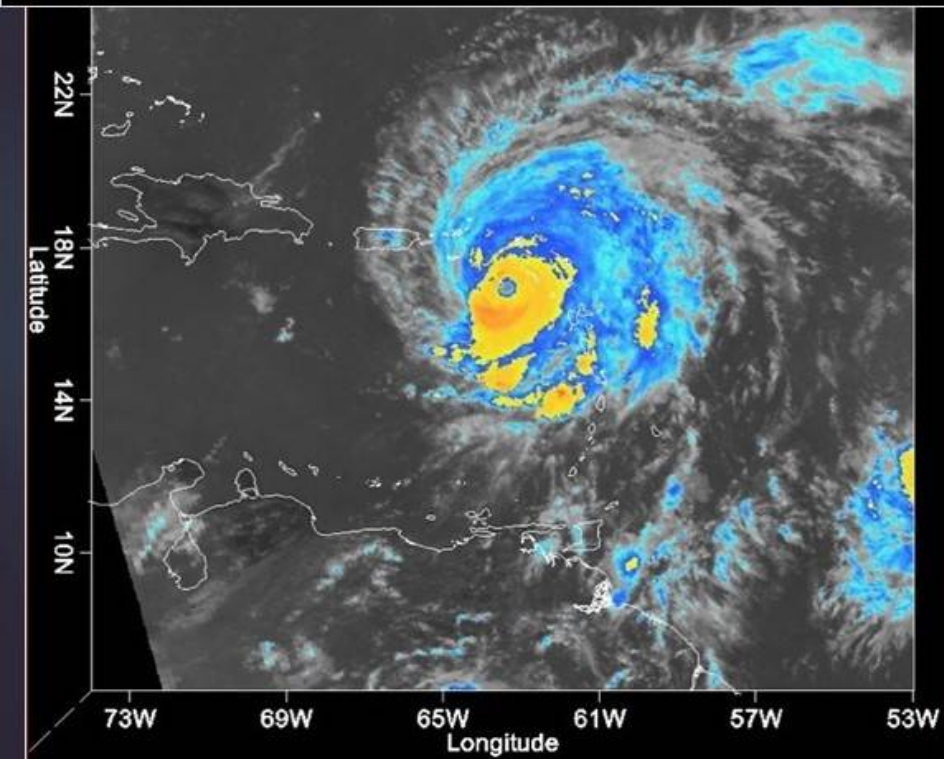


Photo: FEMA, 1999

Virgin Islands' history makes many references to its previous pair of notorious storms -- Hugo (in 1989) and Marilyn (in 1995).

**Hurricane Hugo, September 17, 1989:
Category 4, Winds 138 mph,
Estimated internal pressure 940 mb**

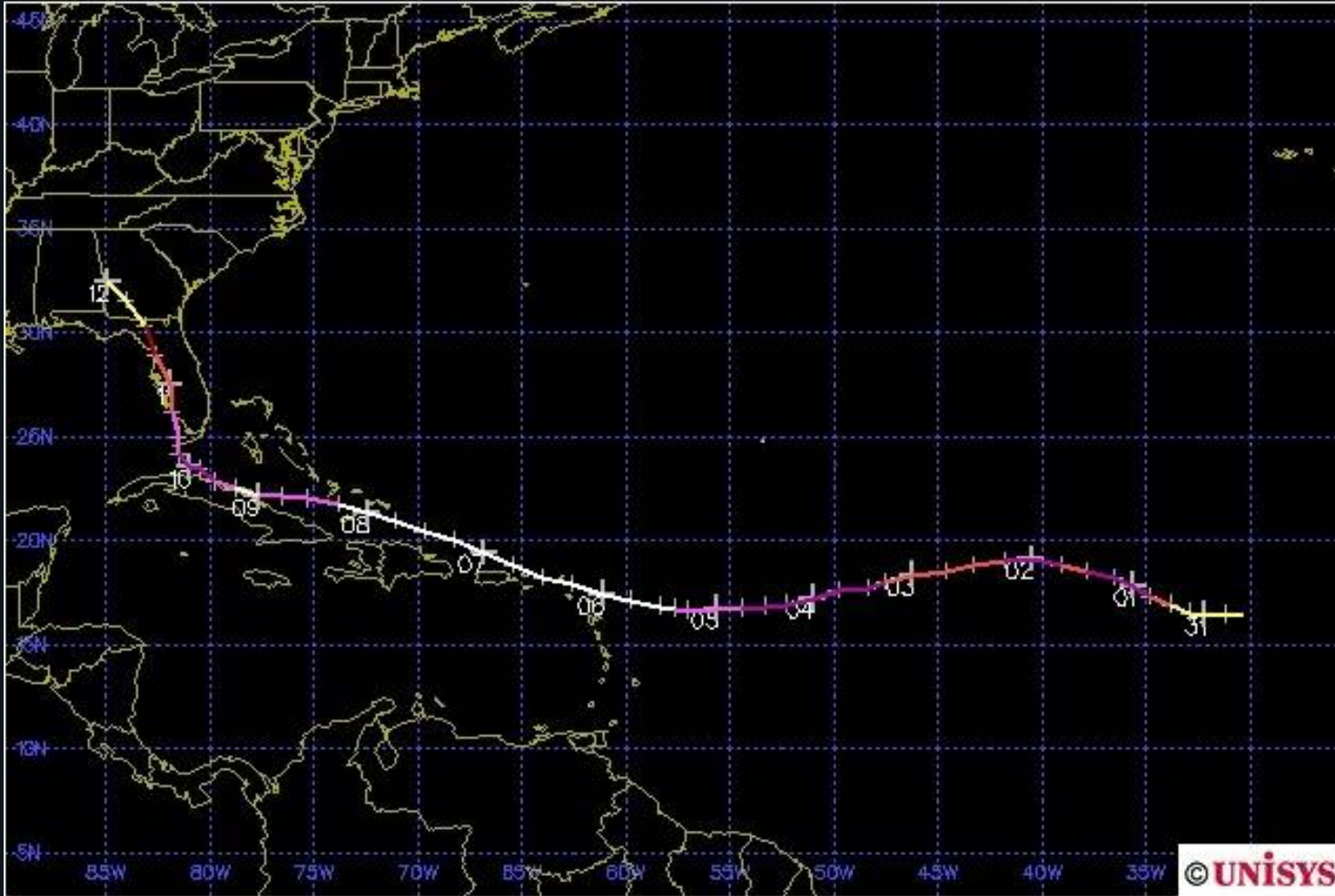
**Hurricane Marilyn, September 15, 1995:
Category 2, Winds 100 mph,
Estimated central pressure 968 mb**



Hurricane-5 IRMA

30 AUG-12 SEP 2017

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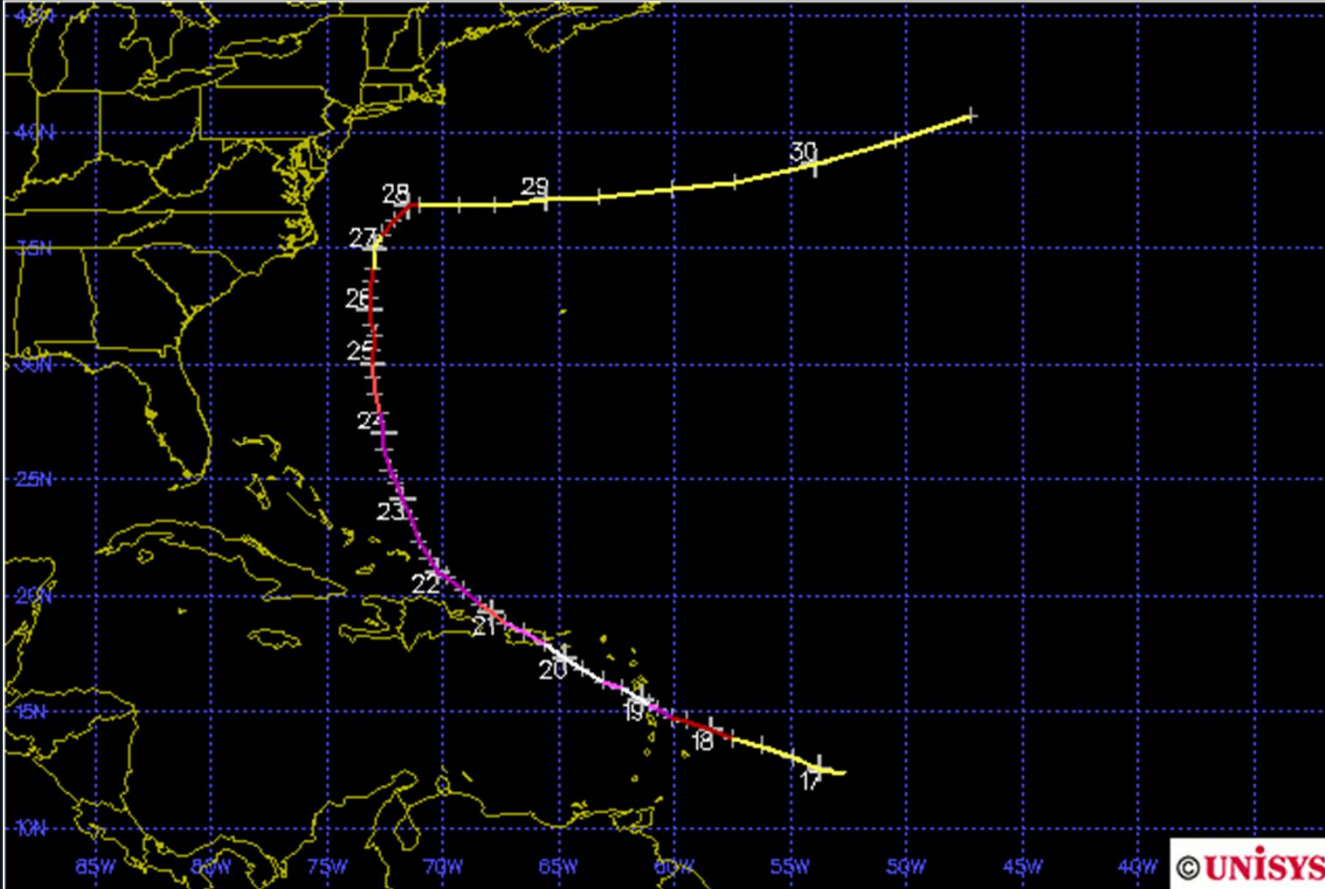
September, 2017:
First came Irma.

Hurricane Irma's path, August 30-September 12, 2017, directed its devastation along the northern coasts of the BVI and USVI

© UNISYS

Hurricane-5 MARIA

16-30 SEP 2017



Then Hurricane Maria

September 17 - 27,
2017, Maria exposed
the Virgin Islands to its
most energetic and
destructive side, with
the eye passing very
close to St. Croix.

Outstanding facts

- ▶ According to meteorologist Eric Holthaus, before Maria, no Category 5 hurricane had struck Dominica since at least 1851 and, prior to Maria, no Category 4 storm had made landfall in Puerto Rico since 1932.
- ▶ The very destructive Hurricane Hugo of 1989 had impacted the US Virgin Islands as a category 4 storm, while the very destructive Hurricane Marilyn impacted the USVI in 1995 as a category 2 storm.
- ▶ Before Hugo and Marilyn, catastrophic hurricanes had hit the Virgin Islands in 1932, 1928 and 1867. The latter, for example, had killed at least 500 people. The publication of Alexander Hamilton's account of the 1772 hurricane in St. Croix is believed to have contributed to the start of his public career.
- ▶ Never before in history has the Virgin Islands been in the cross hairs of two Category 5 hurricanes in the same year, much less only two weeks apart.
- ▶ Hurricane Irma alone had as much Accumulated Cyclone Energy as all of the hurricanes and tropical storms in an entire usual Atlantic hurricane season.

Irma's and Maria's Impacts



▶ Communities significantly affected by Irma:

* Barbuda * St. Martin * Anguilla * British Virgin Islands * USVI * Puerto Rico
* Dominican Republic * Haiti * Turks & Caicos Is. * Cuba * Florida * Georgia

▶ Communities significantly affected by Maria:

* Dominica * Guadeloupe * USVI * All of Puerto Rico * Turks & Caicos Is.

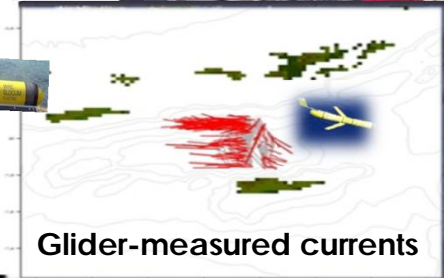
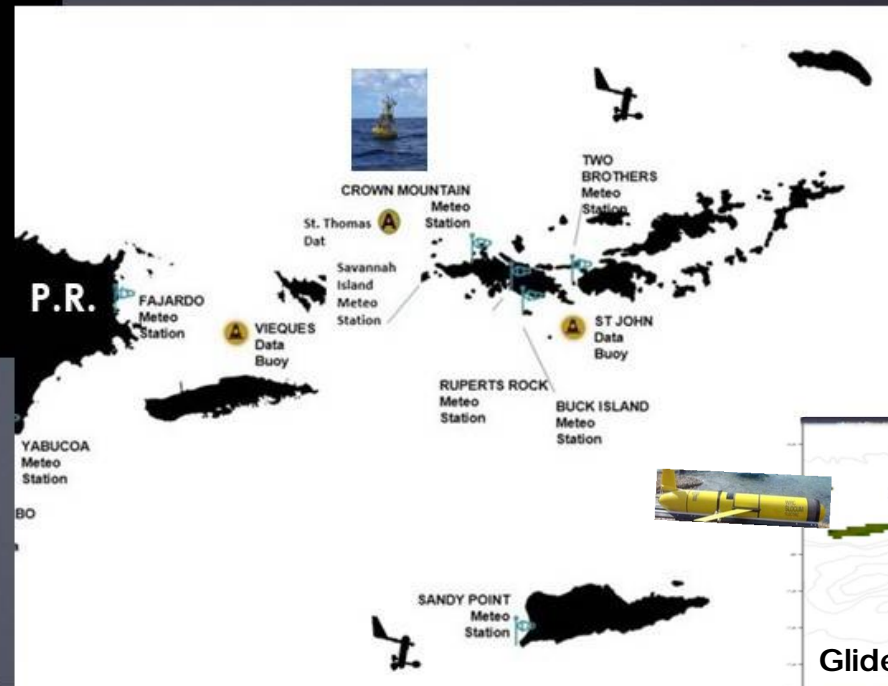
▶ Initial estimates of costs (both storms):

* USVI > \$ 5.5 billion * Puerto Rico: > \$ 65 billion * Caribbean and US ~ \$200 billion

▶ Unconfirmed death toll estimates (all communities):

* >69 for Irma (>38 in the Caribbean) * > For Maria >2000 in PR, >14 in Dominica,

A network of CARICOOS instruments was already deployed, prepared to provide scientific and practical information about hurricanes.



Glider-measured currents



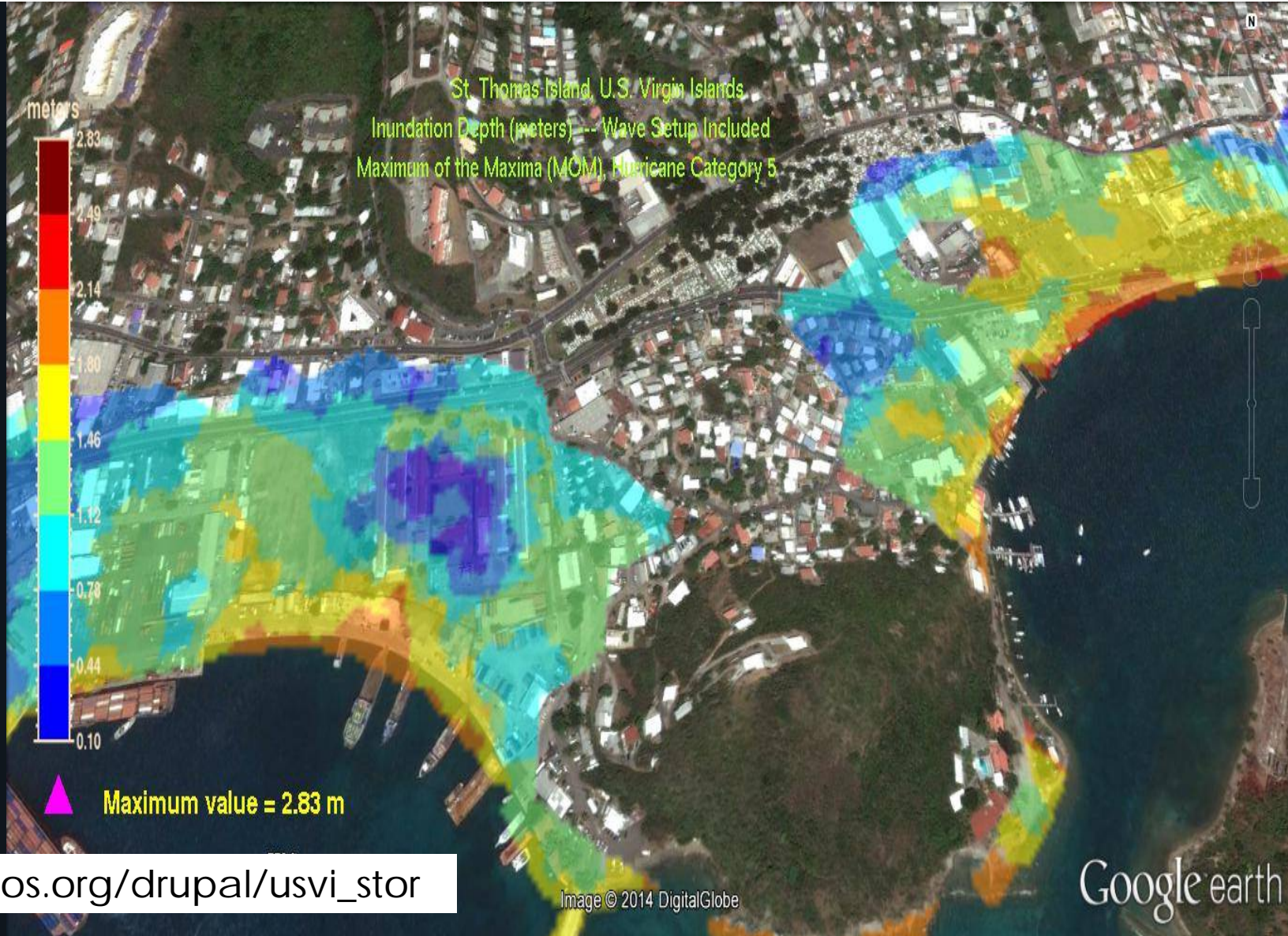
For the most part, they ...
"took a licking but kept on ticking".



INUNDATION
simulation
model
provided by
CARICOOS:

Flooding of
Frenchtown,
St. Thomas by
a Category 5
Hurricane

*Benitez & Mercado,
CARICOOS, 2014*



http://www.caricoos.org/drupal/usvi_storm_surge

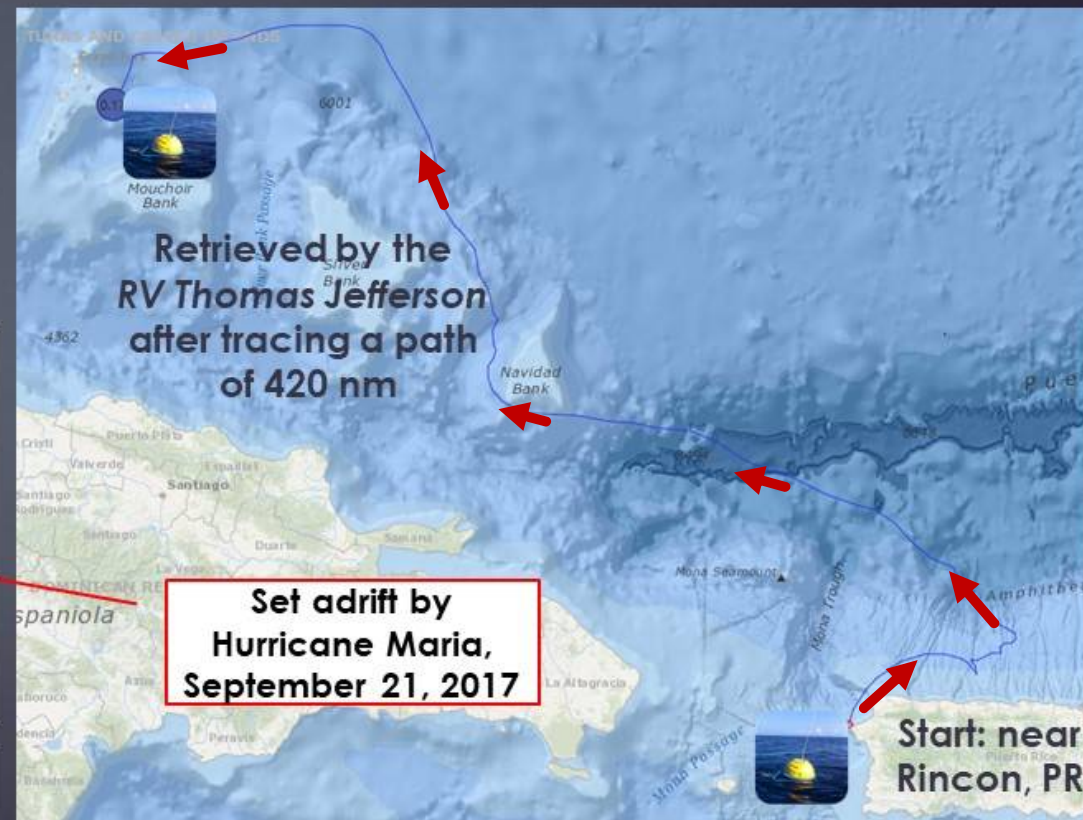
Reports from our instruments



- ▶ UVI's ocean Buoy (NDBC #41058) stopped reporting to CARICOOS after recording a wave height of 23 feet in Hurricane Irma. (On-board electronics recorded 40 ft.) Now recovered by UVI, it requires extensive repair.
- ▶ WeatherFlow®, which provides CARICOOS with its hurricane-hardened weather stations, reports that the weather station at Buck Island, St. Thomas measured wind gusts > 140 mph in Hurricane Irma, while the station at Sandy Point, St. Croix, went silent after reporting gusts > 137 mph in Hurricane Maria.
- ▶ The University of California-San Diego informed CARICOOS that its CDIP wave buoy was torn from its mooring near Rincon after measuring > 7 meter (23 ft) waves and was recovered 275 nautical miles away by the research vessel *R/V Thomas Jefferson*. The buoy's path had covered 420 nm.
- ▶ Most CARICOOS buoys and weather stations were damaged to varying extents during Hurricanes Irma and Maria. Some had stopped reporting before wind speeds reached their true peak. *See: www.caricoos.org/drupal*

CDIP* Wave buoy – operated as an asset deployed with CARICOOS

– was set adrift after recording wave heights > 7 meters



MAXIMUM Wind Speeds and Wind Gusts

Measured during Hurricanes IRMA and MARIA in the US Virgin Islands & Puerto Rico

DATA courtesy of WEATHERFLOW and CARICOOS

Unofficial DRAFT

Some instruments may have failed before experiencing

the true maximum

wind speeds.

Met station data provided by WeatherFlow®

IRMA

MARIA

Weather Station Location

Maximum Wind Speed

Maximum Wind Gust

Maximum Wind Speed

Maximum Wind Gust

(mph)

(mph)

(mph)

(mph)

Buck Island, St. Thomas

105.6

140.9

Tower overturned *

Isla Culebrita Light, PR

102

118.7

124.4

138

Rupert Rock, St Thomas

89.3

132.8

45.3

64.7

Savana Island, St. Thomas

68.9

95.7

Silenced

*

VI CARICOOS Buoy (St. John)

55.9

76.1

47

64.9

VI CARICOOS Buoy (St. Thomas)

55.2

73.6

Silenced

*

PR CARICOOS Buoy (Vieques)

49.2

62.6

62.6

73.8

PR CARICOOS Buoy (San Juan)

44.7

60.4

58.2

76.1

San Juan, PR NAVOID

91

109.6

Sandy Point NWR, St. Croix

44.5

59.1

115.9

137.3

Las Mareas, Guayama, PR

49

54

47.5

69

Del Rey Marina, Fajardo, PR

39.7

68.1

79.5

100.1

Yabucoa, El Negro, PR

38.6

57.3

76.4

116.9

Gurabo, PR

38.5

54.7

89.5

120

Club Deportivo Del Oeste, Mayaguez, PR

36.4

43.8

23.4

32.3

Aguadilla, PR

35.2

48.2

21.6

34.7

PR CARICOOS Buoy (Ponce)

33.6

44.7

58.2

78.3

Please see the OCOVI web page for a more complete chart

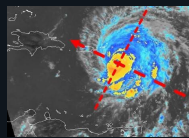
with dates, times

and wind directions

www.ocovi.org

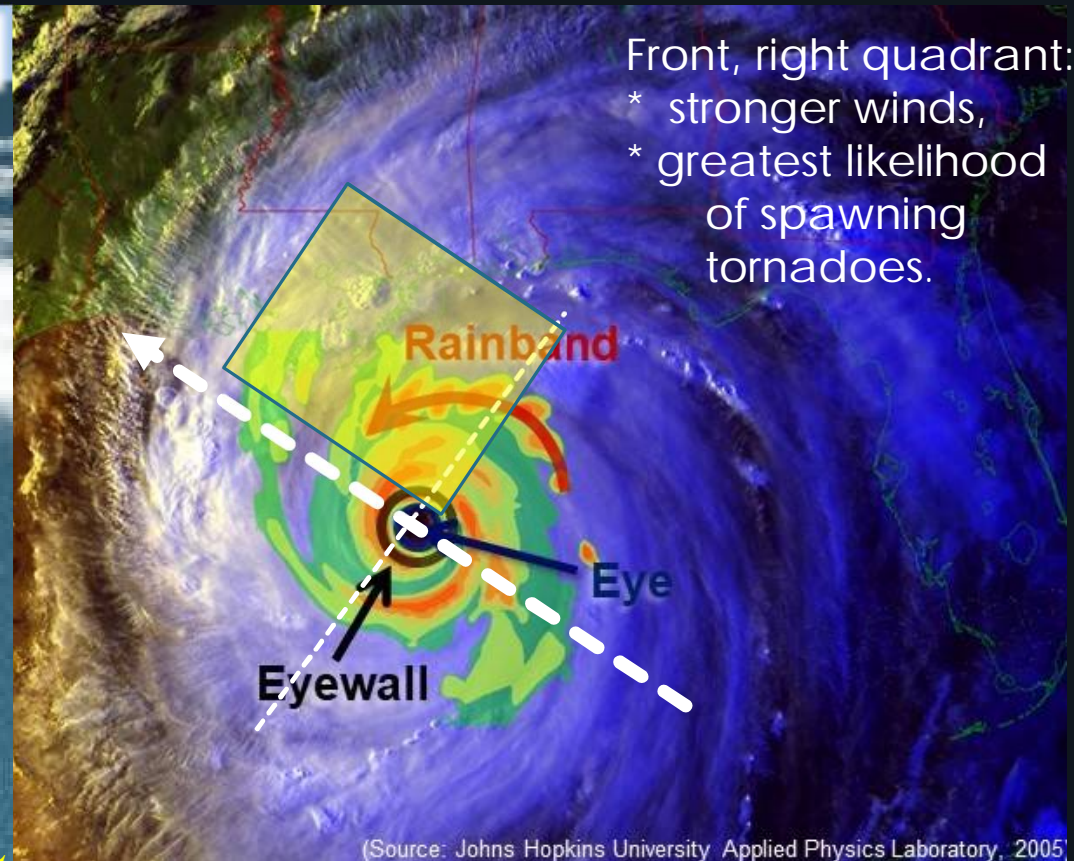
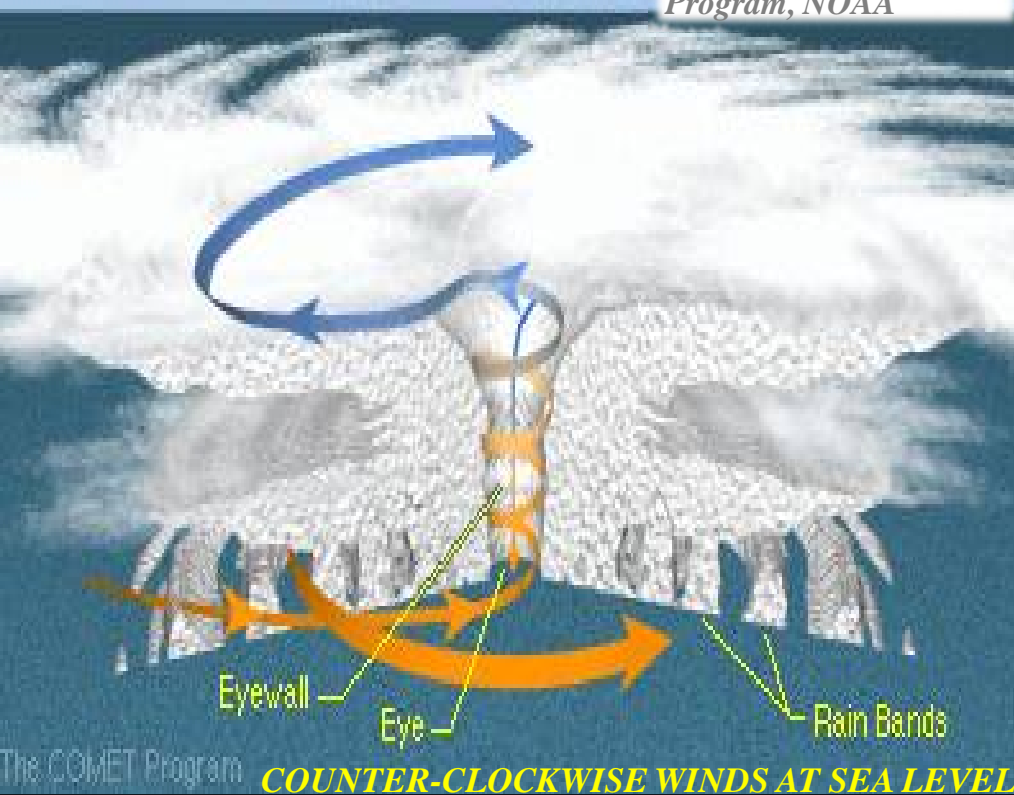
Factors that matter with hurricanes

	What might be most beneficial	What might be disadvantageous
Strength (hurricane category)	Low category number = slower wind speeds	All storms with category rank as well as most tropical storms are destructive.
Internal pressure	Higher pressure within the eye means <u>less</u> intensity	Lower pressure means a <u>more</u> intense storm
Size (extent)	Smaller storms distribute damage over a smaller range	Larger storms affect a wider area
Proximity (closeness of pass)	The farther away the better	Direct impact or near pass of the eye wall is the greatest threat.
Time over the target	Faster moving storm means less time over target and shorter delivery of harm	A slower moving storm means more time over target, more wind and storm surge damage and usually more rainfall
Quadrant of the storm	In the trailing quadrants, the storm's forward motion subtracts from winds' speeds	In the front right quadrant: forward motion adds to wind speeds and to the likelihood of tornadoes there
Elevation	Lower means less wind damage but greater storm surge risk	Higher elevation means stronger winds but less chance of storm surge
Rainfall	Hurricane rains bring few benefits	Flooding, mudslides, penetration of roofs



Structure of a hurricane

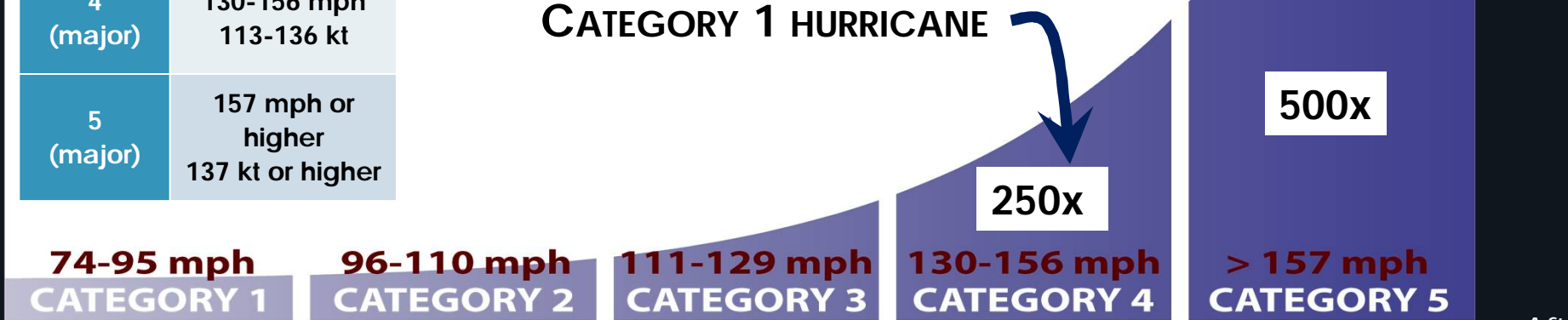
Diagram: The COMET Program, NOAA



Categories: The Saffir-Simpson Hurricane Wind Scale

Category	Sustained Winds
1	74-95 mph 64-82 kt
2	96-110 mph 83-95 kt
3 (major)	111-129 mph 96-112 kt
4 (major)	130-156 mph 113-136 kt
5 (major)	157 mph or higher 137 kt or higher

NOTE THAT
CATEGORY 4 HURRICANE WINDS
ARE LESS THAN TWICE THE SPEED
OF CATEGORY 1 WINDS, BUT
THEY ARE **250X MORE**
DESTRUCTIVE THAN WINDS OF A
CATEGORY 1 HURRICANE

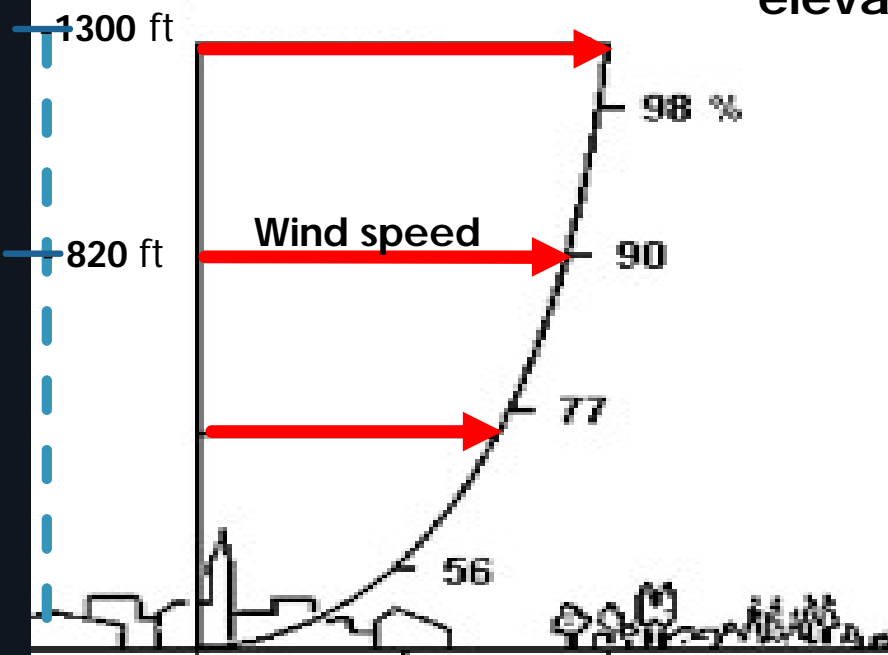


After FEMA

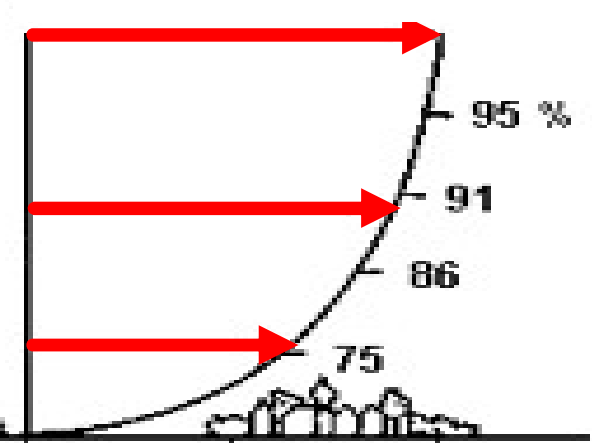
Elevation matters

- Wind speed increases with elevation
- Over open land or open sea, high speeds occur at lower elevations

Residential profile



Open land or sea



After Stadtentwicklung
& S.S. Jahargirdar

The wind speeds that the National Hurricane Center predict are based on hurricane hunter overflights, dropsondes, pressure measurements and analysis of satellite observations – extrapolated to the strongest wind possibility – over the surface (open land or water) -- along the lines of these curves.

The storms of 2017 have seriously affected ocean observing capabilities

VI-A Buoy (#41058),
Virgin Passage,
damaged and silent



Two Brothers
Weather Station,
St. John, damaged
and silent



Buck Island Weather
Station, St. Thomas,
tower toppled but
instrument not silent:

Recovered in the
bush on Buck Island,
the anemometer had
recorded
gusts of
141 mph



Crown Mountain
Weather Station,
St. Thomas,
damaged
and silent



Sandy Point Weather
Station, St. Croix,
damaged but not silent

But the St. John buoy and
other familiar assets fared
better and are still reporting
useful data, available at
caricoos.org & ocovi.org
Most damaged instruments
will be repaired, redeployed
and returned to service.

Challenges after hurricanes: Serious storms affect the economy

General Fund Revenues (FY 1995 - FY 1999)
Government of the U.S. Virgin Islands



...after
Hurricanes
Marilyn (1995)
and
Bertha (1996)

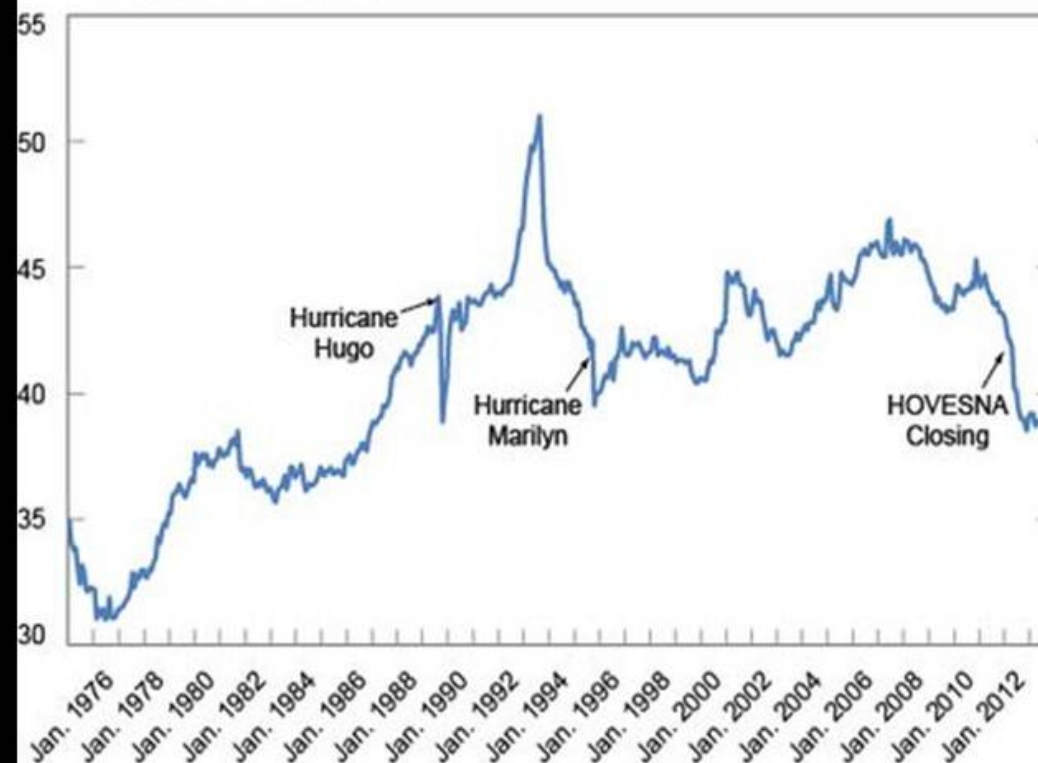
Source: Department of Finance, General Fund Statement of Revenues
Note: General Fund revenue figures do not include contributions.

“Revenues in 1996 were down approximately 8.1 percent to \$347 million (mostly due to a drop in revenues after Hurricanes Marilyn and Bertha)...”

<http://www.usvi.org/oit/5yrplan/>

Total Employment: U.S. Virgin Islands

Thousands, Seasonally Adjusted



Sources: U.S. Bureau of Labor Statistics; Haver Analytics.

Serious storms affect the natural world



... but it's
coming
back.



Serious storms also affect the people

... and they're coming back as well.



Daily News photo by DEAN GREENGLIFF
Marge Smith who worked along with Tony Rosario in St. Thomas, passes out relief supplies in Road Town on Tuesday



A photograph of a sunset over the ocean. The sky is a deep blue, with a bright yellow and orange glow from the sun setting behind a layer of clouds. The sun is partially obscured by a large, dark palm frond that hangs down from the top left corner of the frame. The ocean is a calm, dark blue, and a small, dark silhouette of a boat is visible on the horizon. The overall mood is serene and contemplative.

...For the sun also rises ...

*ocovi.org
--- on behalf of CARICOOS.org*